CRC 990 - EFForTS

NEWSLETTER

Highlights and Closure
Phase 3 | 2020–2023

Issue 9 / Sep 2023

Photo Cover: At the frontier between rainforest and oil palm plantations, Jambi, Sumatra, Indonesia. (Picture credits: Ananggadipa Raswanto)

Content

Acknowledgement from the Management

We are pleased and proud to present the final Newsletter of EFForTS right in time for our closing symposium in Yogyakarta. Despite we faced serious Coronavirus constraints in our work in the field much has been achieved. The Newsletter presents these achievements in a very impressive way.

We would like to take this opportunity to thank all PIs, counterparts, researchers and EFForTS staff for their continued and sincere commitment to the project. This has been and continuous to be a truly joint effort! Once again, we would like to give special thanks to our project coordinators, Barbara Wick and Aiyen Tjoa, for putting together this last Newsletter.

Enjoy reading!

Stefan Scheu & Iskandar Z Siregar

I. Highlights and closure 2022 & 2023

1. Research acivities of groups A, B, C, Z02, INF and Public Relations

Group A

FIELDS OF RESEARCH

- Environmental processes

GROUP COORDINATORS

- Dirk Hölscher, Marife Core (University of Göttingen, UGoe);
- Suria Darma Tarigan (IPB University);
- Muhammad Damris (University of Jambi, UNJA)

A01

TITLE: **Long-term vegetation dynamics, plant phenology and plant-pollinator interactions in rainforest and rainforest transformations in central Sumatra**

TEAM: Principal Investigators: Hermann Behling (UGoe); Rika Raffiudin, Nina Djuita (IPB University); Asmadi Saad (UNJA).
Scientific Staff: Svea Lina Jahnk (Doctoral Researcher, UGoe).
Associated Scientists: Kartika Anggi Hapsari (Postdoctoral Researcher, UGoe), Chung Nguyen (Doctoral Researcher, UGoe).

RESEARCH SUMMARY:

Facing continuous rainforest transformation since the past decades it is essential to understand how tropical ecosystems function under long-term disturbance, not only in the presence but also in the past. The study of phenological responses to environmental and anthropogenic disturbances at different temporal scales, as provided by paleoecological and modern palynological approaches can help to clarify some of the mechanisms behind ecosystem dynamics.

Our investigations on recent pollen and spore rain as well as environmental archives throughout Jambi Province provided not only a nine-year record of interannual phenological dynamics in different land use systems but

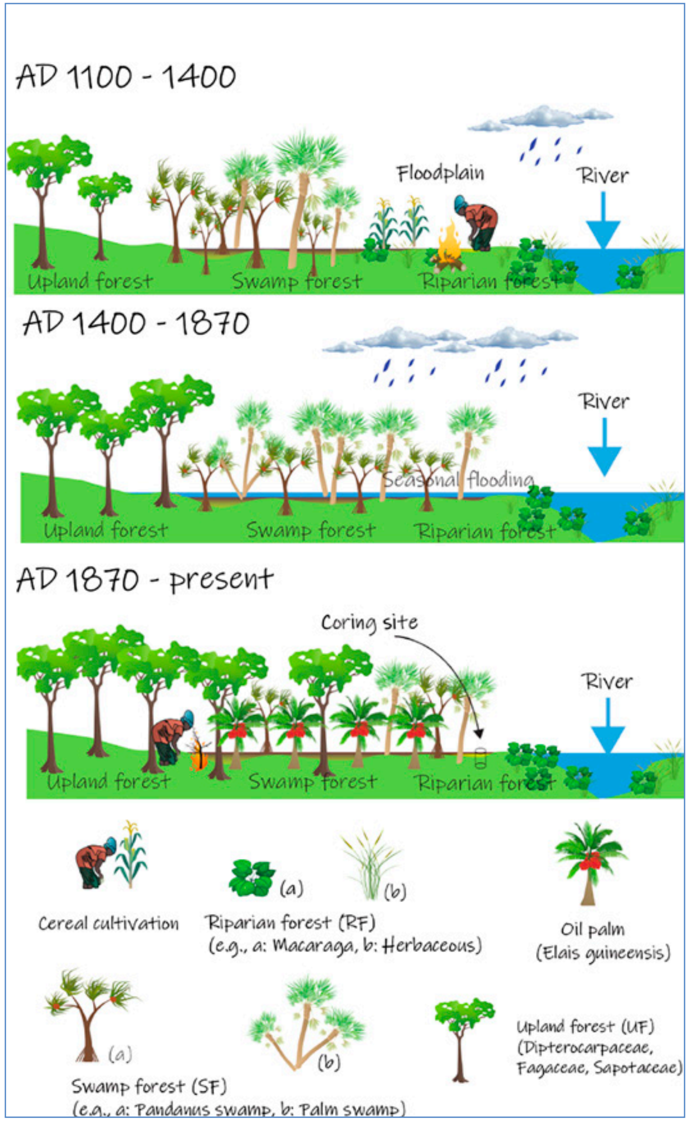


Figure 1. Transformation phases of the Harapan riparian area towards freshwater swamps during the past 900 years. Agricultural activities and flooding have been the probable causes.

Picture 1. Fieldwork at Danau Kecil (Nguyen *et al.* 2022) in Kerinci Seblat National Park, Jambi 2022 (Left to right: Reza Mardhony, Svea Lina Jahnk, Chung Hoai Nguyen and Bambang Harisyanto).

also a set of 12 sediment cores alongside an elevational, east-west gradient from the mountains to the coast. Results of the modern pollen rain composition in four different land use systems imply decreasing palynological diversity with increasing land use intensity and inter-annual phenological phases related to the climatic El Niño Southern Oscillation (ENSO) phenomenon. Our participation in the Landscape Assessment project through modern pollen rain and pollen collected by stingless bees (in cooperation with B09 and B14) will upscale our results to the landscape scale and answer follow-up questions such as the role of landscape heterogeneity on pollen dispersal and composition. Preliminary results of our intra-annual studies on modern pollen rain in 3-month intervals at the B11-Biodiversity Enrichment Experiment plots on the other hand showed a degree of palynological seasonality, expressed in pollen and spore influx and diversity.

Our various paleoecological studies supplied a history of human influence and environmental dynamics (such as climatic influences, sea level change and volcanic activity) at 12 different locations in Jambi Province. E. g., one recently studied sediment core at a riparian site in Harapan forest revealed that within less than 1000 years, the riparian zone was transformed into freshwater swamps in the Harapan forest. Changes in precipitation and flooding drove the changes in vegetation composition in the riparian zone in the Harapan forest and early agricultural activities with a slash-and-burn method employed by the indigenous people also played a role (see also Fig.1). We aim to "upscale" the paleoecological and -environmental approach by conflating the results of analysed sediment cores. Our study on modern pollen rain highlights several taxa, suitable to record and compare environmental changes between cores and alongside a landscape heterogeneity gradient. Consequently, we may be able to access past landscape transformation through time and space.

A02

TITLE: **Tree and palm water use**

TEAM: Principal Investigators: Dirk Hölscher (UGoe); Hendrayanto, Agusta Herdhata (IPB University).
Scientific Staff: Medha Bulusu (Doctoral Researcher, UGoe).
Associated Scientists: Alexander Röll (Postdoctoral Researcher, UGoe), Pallavi, Thorge Wintz (Doctoral Researchers, UGoe).

RESEARCH SUMMARY:

We study evapotranspiration, which is a central flux in the hydrological cycle. Evapotranspiration is also an important process in climate regulation and may strongly be affected by land-use change. Established methods for evapotranspiration assessment include ground-based and space-borne approaches, which can be limited in spatial or temporal resolution or due to cloud cover. Near-surface operating drones equipped with adequate sensors and a modelling framework may help to bridge such gaps. We tested drone-based thermography with subsequent energy balance modelling against well-established ground-based methods, and derived evapotranspiration characteristics in the mosaic landscape of lowland Sumatra.

Comparing the results of the drone-based approach with eddy-covariance measurements for an oil palm plantation, we observed a very high agreement between the two methods yielding statistical interchangeability. The coverage of spatial heterogeneity was tested using sap flux methods as a reference in forests and oil palm agroforests and likewise yielded convincing results. Evapotranspiration rates predicted by the drone-based approach were similar for oil palm plantations and the rainforest.

In more detailed studies in the Harapan rainforest (Picture 2), we found that evapotranspiration is mediated by site characteristics and season. Using drone-derived point cloud data, we showed that 3-D canopy structure in the rainforest controls tree transpiration rates. Machine learning was applied to predict ET from the rainforest and to analyse variable importance. At the time of report writing, we have three manuscripts under review at scientific journals.

In the heterogenous mosaic landscape, drone-based assessments are applied to assess differences in evapotranspiration rates among land-use types (Fig. 2) and the importance of edge effects. We further contributed to the joint landscape assessment by measuring canopy leaf area index and below-canopy surface temperatures (vegetation, soil, black-and-white chessboard, hijab and cap). These studies were extended to EFForTS-OP-MX and EFForTS-BEE. The drone-based studies are being continued to study land surface temperature, evapotranspiration, albedo and vegetation indices also in view of the upcom-

Picture 2. Measurements of tree transpiration for 'ground-referencing' in the Harapan rainforest (left). Preparing a drone for a flight mission to study land surface temperatures and evapotranspiration in the Harapan rainforest (right).

ing ENSO event. We frequently re-visit the eddy-covariance tower for ground-referencing, and assess rubber plantations, oil palm plantations, shrubland and the biodiversity enrichment experiment EFForTS-BEE.

Our studies contributed to major syntheses on the role of tree islands in a sea of oil palms (Zemp *et al.*, 2023, EFForTS-BEE) and on trade-offs in oil palm cultivation (Wenzel et al, under review). Overall, we want to better understand ecohydrological consequences of land-use change and address climate regulation effects of land transformation.

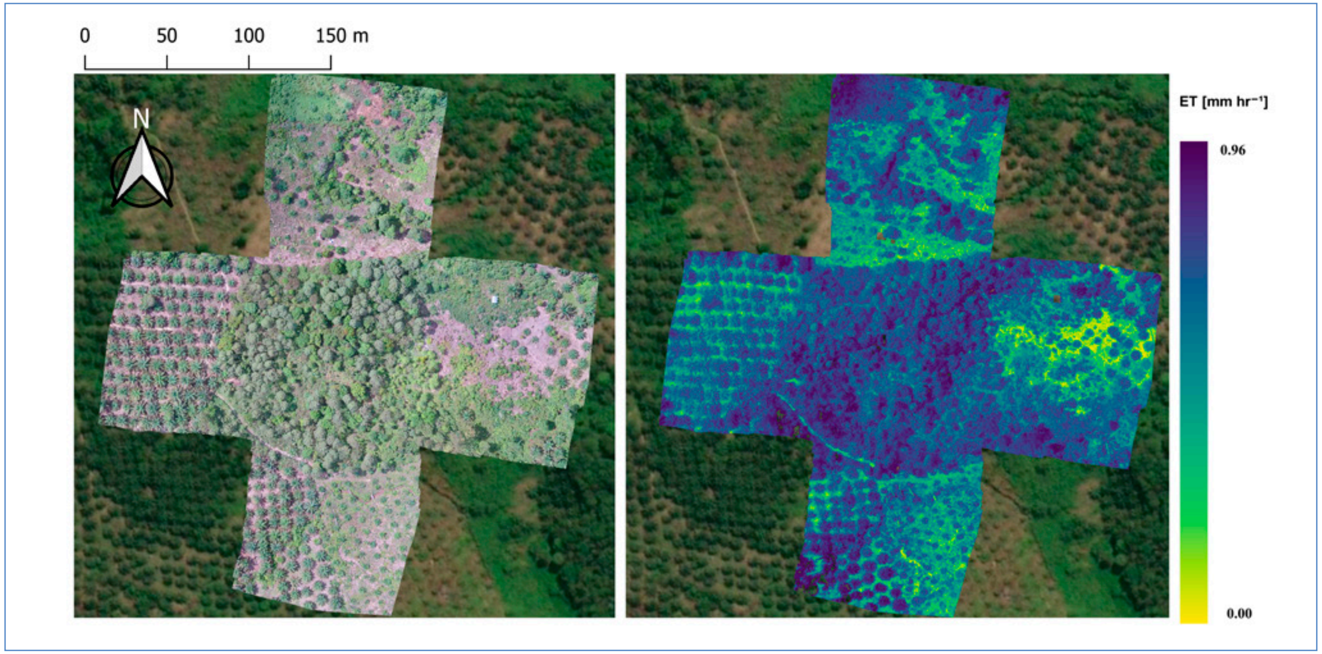


Figure 2. Drone-based assessments in the Harapan landscape with a 'truecolor' red-green-blue map (left) and an evapotranspiration map (right). Evapotranspiration (ET) from the secondary forest patch in the center is about 20% higher than from the western oil palm plantation. For the ET map: Flight time 2 pm; incoming shortwave solar radiation 820 W m^{-2}, resolution 10 cm per pixel. (Bulusu *et al.* unpublished).

A03

TITLE: **Understanding land-atmosphere exchange processes in land-use transformation systems**

TEAM: Principal Investigators: Alexander Knohl, (UGoe), Tania June (IPB University), Dodo Gunawan (Badan Meteorologi Klimatologi dan Geofisika, Indonesia, BMKG), Abdul Rauf (University of Tadulako, UNTAD).
Scientific Staff: Christian Stiegler (Postdoctoral Researcher, UGoe).
Associated Scientists: Jonathan Jürgensen (Doctoral Researcher, UGoe)
Technical Staff: Marek Peksa, Edgar Tunsch, (UGoe).

Picture 3. A03 field team happily reunited after long Covid-19 related break.

RESEARCH SUMMARY:

Within A03, we studied land-atmosphere exchange processes in land-use transformation systems in Jambi province by performing continuous microclimatic and eddy covariance (EC) measurements at a commercial oil palm plantation (1°41′35.0″ S, 103°23′29.0″ E, 76 m a. s. l.) since mid-2014 to determine (1) carbon- and non-carbon land-atmosphere exchange processes in oil palm; and (2) greenhouse gas (GHG) and water balance of oil palm.

During the period 2014 to 2020 the studied oil palm plantation was a strong net sink of carbon dioxide (CO_2), with average CO_2 net ecosystem exchange (NEE) of -2.3 ± 0.04 standard deviation µmol m^{-2} s^{-1} (Fig. 3). Oil palm showed a distinct reaction to changes in atmospheric and soil parameters that is reflected in the observed NEE and gross primary productivity (GPP). For example, favourable conditions for oil palm productivity in 2018, i. e. relatively high soil moisture conditions even during the dry season and no pronounced drought periods, resulted in significantly stronger carbon uptake (NEE of -3.4 ± 0.11 µmol m^{-2} s^{-1}, p-value <0.05) compared to the other years. Contrary, in 2015, the strongest El Niño–Southern Oscillation (ENSO) observed in almost 20 years set the stage for low carbon uptake (-1.8 ± 0.09 µmol m^{-2} s^{-1}) due to the combined effect of severe drought and reduced light conditions due to haze from vast forest fires (Stiegler *et al.*, 2019). Moreover, haze conditions in 2015 resulted in a complete pause of oil palm net carbon accumulation for about 1.5 months and contributed to a decline in oil palm yield by 35%.

The studied oil palm plantation has a high water demand, expressed by high rates of evapotranspiration (ET), on average, 3.6 ± 0.02 SE mm day^{-1} (Meijide *et al.*, 2017) (Fig. 3). The oil palms' high water demand and ET be-

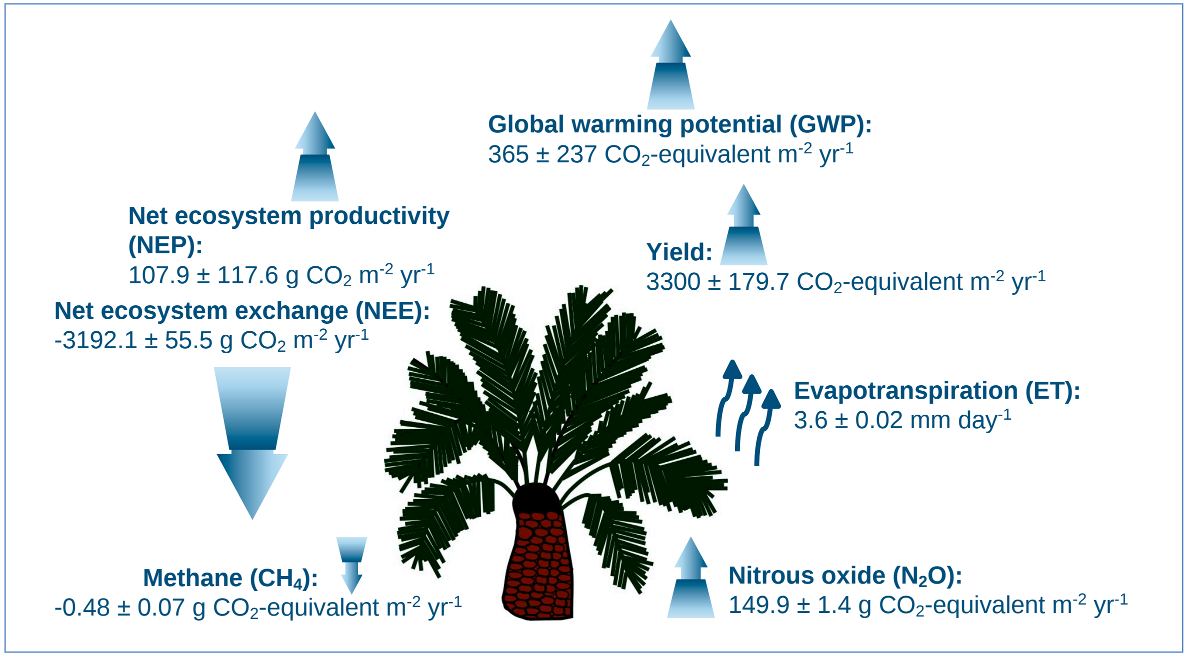


Figure 3. Measured greenhouse gas balance and evapotranspiration at the oil palm plantation. Negative values indicate uptake, positive values indicate emission.

come crucial especially during the dry period, when total precipitation drops below approx. 100 mm $month^{-1}$ and soil moisture decreases concurrently. Oil palm has limited adaptation strategies to these conditions and with increasing duration of drought conditions, highly non-linear ecosystem responses may occur, i. e. additional warming effect and increase in surface temperatures due to reduced evaporative cooling effects.

Based on EC measurements, the studied oil palm plantation showed up to 77% higher nitrous oxide (N_2O) emissions compared to natural forest systems in Jambi province (Ishizuka *et al.*, 2005; Hassler *et al.*, 2017), making it an important local anthropogenic source of N_2O (Fig. 3). The combined global warming potential of NEE (-3192.1 ± 55.5 CO_2 m^{-2} yr^{-1}), harvest (3300 ± 179.7 CO_2-equivalent m^{-2} yr^{-1}), N_2O (149.9 ± 1.4 CO_2-equivalent m^{-2} yr^{-1}) and methane (CH_4) fluxes (-0.48 ± 0.07 CO_2-equivalent m^{-2} yr^{-1}) was 365 ± 237 g CO_2-equivalent m^{-2} yr^{-1} indicating a net warming greenhouse gas effect of the oil palm plantation.

Since November 2022, hyperspectral (visible and near-infrared) and sun-induced fluorescence (SIF) measurements, accompanied by measurements of radiation components, e. g. above- and below-canopy photosynthetically active radiation (PAR) and above-canopy short-, longwave, global and diffuse radiation, are used for estimating ecosystem-scale photosynthesis (GPP), photosynthetic capacity and plant vitality or stress. This measurement setup opens new, yet not explored opportunities to study non-carbon climate regulations, e. g. SIF can be used as a proxy for ecosystem-level transpiration estimates. With respect to ENSO and related drought, as well as oil palm age, carbon flux, radiative response and non-carbon climate regulations in oil palm can be studied more accurately.

References:

Hassler E, Corre MD, Kurniawan S, Veldkamp E (2017) Soil nitrogen oxide fluxes from lowland forests converted to smallholder rubber and oil palm plantations in Sumatra, Indonesia. Biogeosciences 14: 2781-2798 *doi: 10.5194/bg-14-2781-2017*

Ishizuka S, Iswandi A, Nakajima Y, Yonemura S, Sudo S, Tsuruta H, Murdiyarso D (2005) The variation of greenhouse gas emissions from soils of various land-use/cover types in Jambi province, Indonesia. Nutrient Cycling in Agroecosystems 71: 17-32 *doi: 10.1007/s10705-004-0382-0*

Meijide A, Röll A, Fan Y, Herbst M, Niu F, Tiedemann F, Knohl A (2017) Controls of water and energy fluxes in oil palm plantations: Environmental variables and oil palm age. Agricultural and Forest Meteorology 239: 71-85 *doi: 10.1016/j.agrformet.2017.02.034*

Stiegler C, Meijide A, Fan Y, Ali AA, June T, Knohl A (2019) El Niño-Southern Oscillation (ENSO) event reduces CO2 uptake of an Indonesian oil palm plantation. Biogeosciences 16: 2873-2890 *doi: 10.5194/bg-16-2873-2019*

A05

TITLE: **Optimizing nutrient management in oil palm plantations and upscaling greenhouse gas fluxes from plot to a rainforest-transformation landscape**

TEAM: Principal Investigators: Marife D. Corre, Edzo Veldkamp (UGoe); Aiyen Tjoa (UNTAD); Bambang Irawan, Muhammad Damris (UNJA).
Scientific Staff: Najeeb A. Iddris (Postdoctoral researcher, UGoe).
Associated Scientist: Guantao Chen (Doctoral Researcher, UGoe).

RESEARCH SUMMARY:

The intensive management of oil palm plantations leads to an increased leaching of soil nutrients, which in turn diminishes soil fertility and has an adverse impact on water quality. It is therefore imperative to identify practical management solutions that ensure adequate nutrient supply to maintain high productivity while minimizing leaching and gaseous losses of nutrients. Thus, in phase 3, we investigated whether four years of reduced management will decrease nutrient leaching losses compared to current conventional management. In a large-scale oil palm plantation located on Acrisol soil, we quantified soil nutrient leaching using a 2^2 factorial experiment of two fertilization rates × two weeding practices, with conventional vs reduced (that is, equal to nutrients exported with harvest) fertilization rates and herbicide vs mechanical weeding (that is, using brush cutter). Over the course of one year, we collected monthly soil pore water at 1.5 m depth in three distinct management zones: fertilized palm circle, inter-row, and frond-stacked area.

Compared to conventional management, the reduced management decreased nitrogen leaching losses by 74% (Fig. 4). This reduction may be due to the lower fertilization rate in the reduced management, and increased cover and diversity of underground vegetation resulting from replacing herbicide use with mechanical weeding. This together may have enhanced root uptake and recycling of soil nutrients. Additionally, reduced management resulted in a significant reduction of aluminium leaching by 60% and potassium

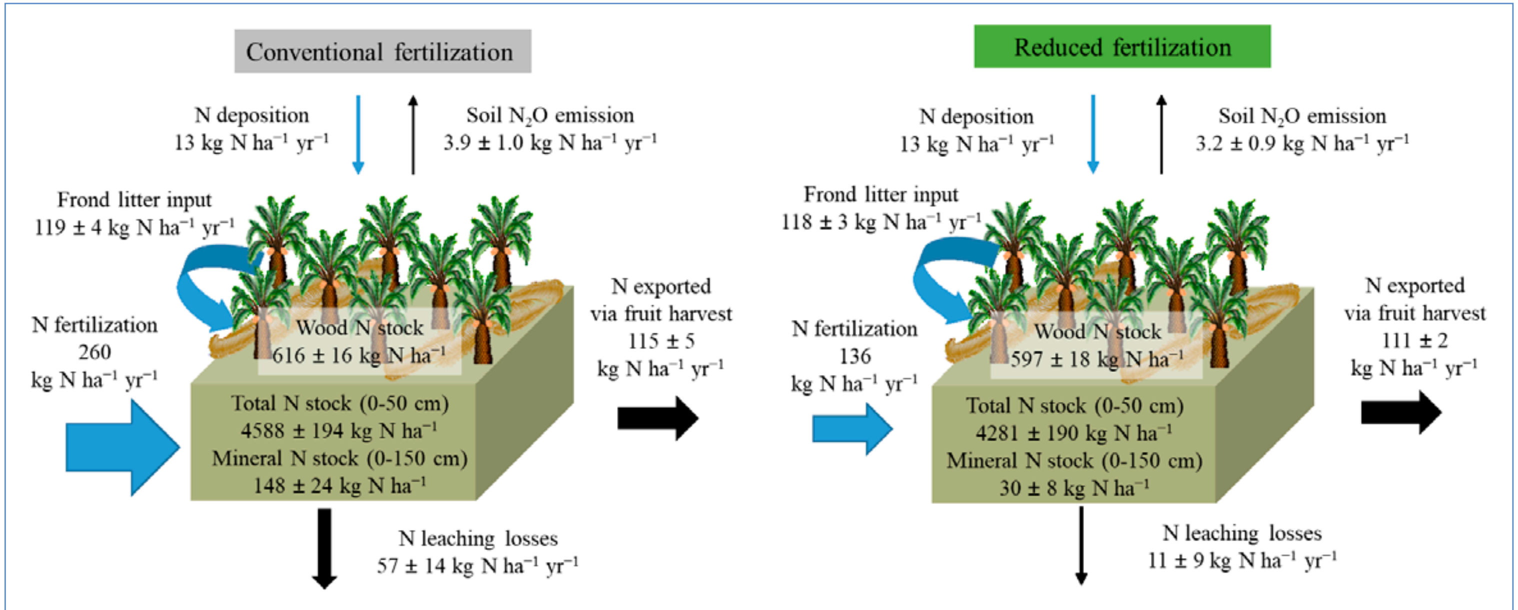


Figure 4. Major nitrogen inputs and outputs from conventional and reduced fertilization treatments (mean ± SE, $N = 8$ plots) in a mature, large-scale oil palm plantation in Jambi, Indonesia. Rainfall N deposition was reported by Kurniawan *et al.* (2018). Nitrogen export from fruit harvest was the average fruit yield of 2019 and 2020 multiplied by the tissue N concentration (Formaglio *et al.* 2021). Nitrogen input from pruned frond leaves was the average frond litter mass of 2019 and 2020 multiplied by the tissue N concentration (Kotowska *et al.* 2016). Nitrogen stock in woody biomass was the average standing woody biomass of 2019 and 2020 multiplied by the tissue N concentration (Siang *et al.* 2022).

Picture 4. Installation of suction cup lysimeters at 1.5 m depth and tensiometers at 0.3 m and 0.6 m depths in each management zone per replicate plot.

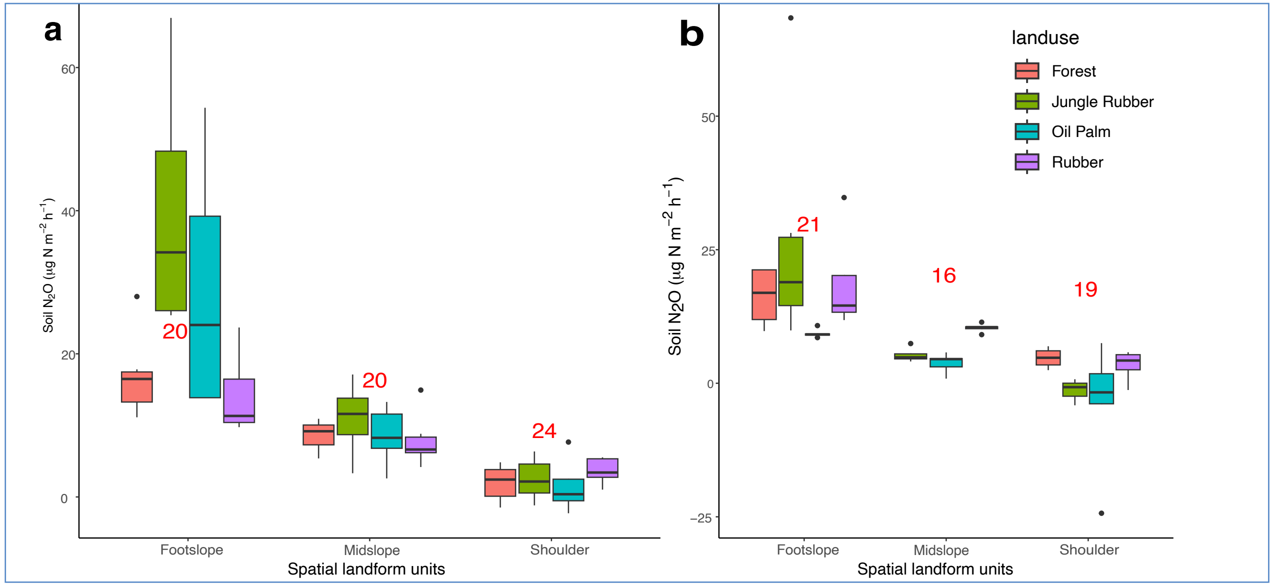


Figure 5. Relationship between soil nitrous oxide (N_2O) fluxes and spatial landform units on loam Acrisol soil **(a)** and clay Acrisol soil **(b)** in Jambi, Indonesia. Numbers in red indicate the number of plots per spatial landform unit.

leaching by 73% compared to conventional management. Among the management zones, the palm circle had higher nitrogen leaching fluxes compared to the inter-row and frond-stacked area, which was due to the high nitrogen solute concentrations in this zone as a result of direct fertilizer application. Despite the reduced fertilization rate, reduced management was as effective in attaining similar yield as the conventional management. Thus, our results suggest that mechanical weeding together with reduced, compensatory fertilization rates, are viable alternatives to current conventional management practices in reducing nitrogen leaching losses without sacrificing yield. Our findings suggest that mechanical weeding and reduced fertilization should be included in the program by the Indonesian Ministry of Agriculture for precision farming (e. g., variable rates with plantation age), particularly for large-scale oil palm plantations.

A second part of our project aims to produce landscape-scale estimates and maps of soil nitrous oxide (N_2O) fluxes for different land uses in the Jambi region. Here, we used the landscape segmentation approach to investigate the relationship between three distinct spatial landform units and soil N_2O fluxes measured from the 1st and 2nd phase of the CRC-EFForTS project. Our results revealed a consistent landscape-scale pattern of N_2O emission; footslope positions had higher N_2O fluxes than shoulder positions (Fig. 5). This may be attributed to the strong influence of topography on the hydrologic and pedologic processes in the landscape, which, in turn, regulate the soil factors controlling N_2O emission at the microscale level. These predictive relationships will serve as the basis for creating maps of soil N_2O fluxes for different land uses in the Jambi region.

A07

TITLE: **Spatio-temporal scaling of the impacts of land-use and climate change in land transformation systems in Indonesia**

TEAM: Principal Investigators: Alexander Knohl, Edzo Veldkamp (UGoe); Tania June, Surya Tarigan (IPB University).
Scientific Staff: Ashehad Ali (Postdoctoral Researcher, UGoe).
Asscociated Scientists: Yuanchao Fan (Assistant Professor, Tsinghua University), Fernando Moyano, Rahmi Ariani (Doctoral Researcher, UGoe), Ummu Ma'rufah (Doctoral Researcher, IPB University).

RESEARCH SUMMARY:

Biogeochemical cycles of carbon and water fluxes of tropical woody vegetation from lowland areas can vary spatially at regional levels due to a number of reasons: differences in deforestation rates, differing management practices, differences in tree ages, logging and fires. The variability of the fluxes is often caused by a combination of the above factors and so land surface models can be used to investigate the flux variations, but they have not been tested or evaluated in land use transformation systems in Indonesia due to the complex representation of processes, high dimension of parameters, and lack of available data. Therefore, in the second part of Phase 3, we first obtained the landscape-level ecosystem state data that were collected in a landscape assessment framework in the lowland area of the Jambi Province in Indonesia. Next, we used a land surface model (the Community Land Model; CLM5) and focused on tropical evergreen forest, oil palm, and rubber plant functional types (PFTs). Using CLM5, we performed two sets of simulations for the above PFTs; one included running a baseline case and the other included running the model after modifying the above three PFTs' ecosystem state for leaf area index, the ratio of leaf carbon to nitrogen and litter carbon (referred hereafter as the initialized case). Both sets of simulations used oil palm and rubber PFTs that were calibrated using plot-level ground data.

The baseline CLM5 predicted relatively higher values of leaf area index for oil palm and forest PFTs compared to the rubber PFT (Fig. 6b). The leaf area index values of rubber and forest PFTs increased while the leaf area index value of oil palm PFT decreased in response to initialization (Fig. 6c). Using 2016's meteorological data and recycling it over three years, the spatial patterns of leaf area index of baseline and initialized cases looked similar (Fig. 6d). For site-level simulation, CLM5 predicted contrasting monthly mean values (and temporal dynamics) of leaf index for forest, rubber, and oil palm PFTs for both the baseline and initialized cases (Fig. 6e). CLM5 predicted the fastest return of leaf area index to its baseline value for the rubber PFT (Fig. 6e). On the contrary, CLM5 predicted the slowest return of leaf area index to its baseline value for the oil palm PFT (Fig. 1e). Overall, CLM5 predicted that all PFTs would return to their baseline value within three years (Fig. 6f) – indicating that these PFTs might be highly resilient to the above ecosystem state (i. e. leaf area index, the ratio of leaf carbon to nitrogen and litter carbon) perturbations.

The calibration of the tropical evergreen forest PFT demonstrated that optimizing parame-

Picture 5. Field assistants of A07 measuring leaf-gas exchanges as part of the landscape assessment framework in 2021. The measurement campaign was in the Jambi Province in Indonesia.

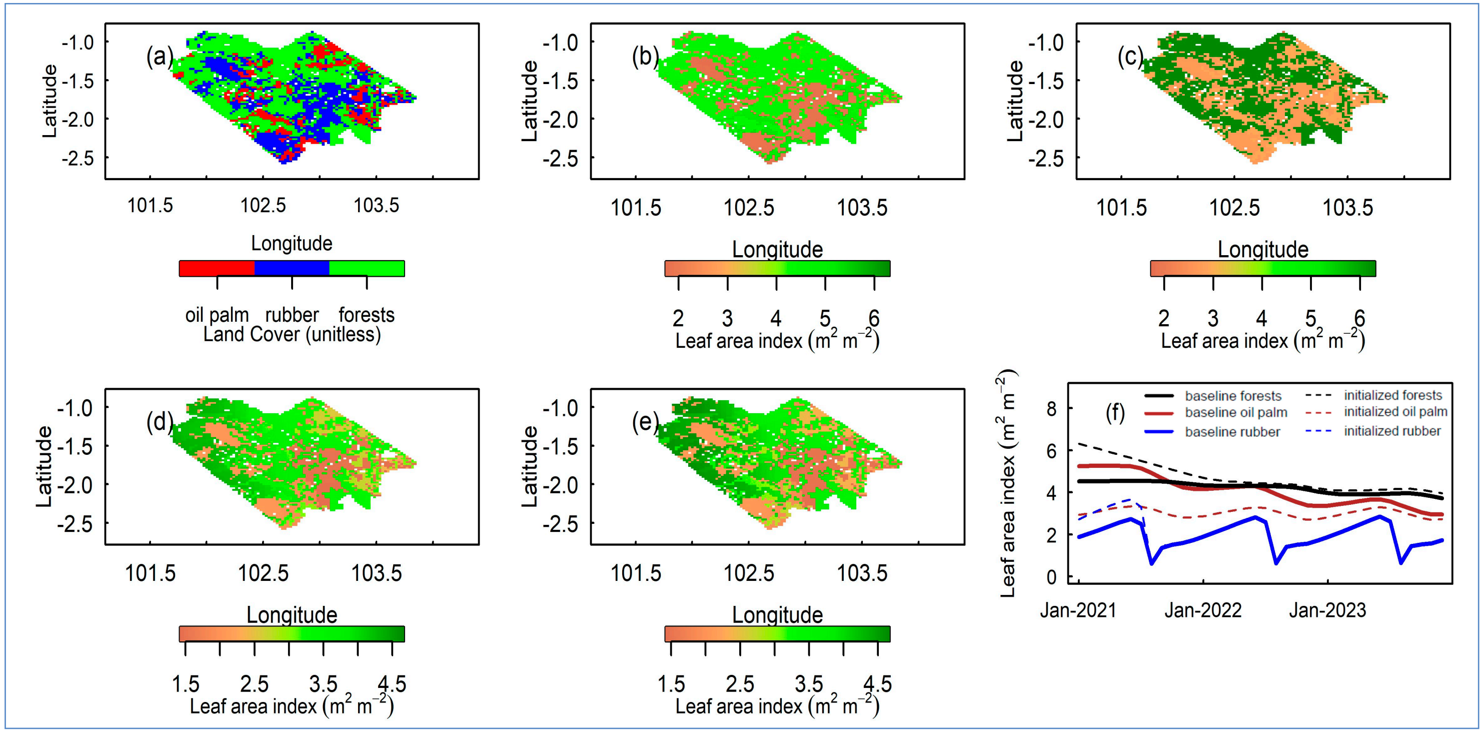


Figure 6. Land cover map of oil palm, rubber, and forests (a), baseline case leaf area index of CLM5 for January 2021 (b), initialized case leaf area index of CLM5 for January 2021 (c), baseline case annual leaf area index of CLM5 for 2023 (d), initialized case annual leaf area index of CLM5 for January 2023 (e) and monthly trends of leaf area index of CLM5 of forests, oil palm and rubber for baseline and initialized cases for a non-random pixel (f). The figure is taken from Ali *et al.* (unpubl. data).

ter values led to a significant improvement in the CLM5's prediction, where the sum of squared errors was reduced by 50% (results not shown here). The calibrated model was then tested for three different forest locations in Southeast Asia, and notable improvements were observed in predicting carbon fluxes and stocks at all sites (results not shown here).

When CLM5 model was ran with the El Nino Southern Oscillation meteorological data, the model's gross primary productivity and net primary productivity for tropical evergreen forests significantly declined (Ma'rufah *et al.* 2022), particularly in October and November when there was an increased number of days without rainfall. In addition, CLM5 predicted a considerable decrease in the value of difference between latent and sensible heat flux from August to November (Ma'rufah *et al.* 2022).

In the remaining part of Phase 3, we will a) quantify the impacts of the land-use change and climate change on biogeochemical cycles of oil palm and rubber plantations in the lowland areas and b) explore possibilities of environmentally friendly ecosystems (or 'win-win' situations) for rubber and oil palm PFTs using CLM5, where we will look into agroforestry systems in CLM5. From the photosynthetic capacity data sets that we collected in the landscape assessment framework, we will gain insights into how conservative the physiological parameters are within a plant functional type and how the stacking of carbon in leaves varies among coexisting species.

Group B

FIELDS OF RESEARCH

- Biota and ecosystem services

GROUP COORDINATORS

- Holger Kreft, Martyna Kotowska (UGoe);
- Leti Sundawati (IPB University);
- Upik Yelianti (UNJA)

B04

TITLE: **Plant productivity and belowground resource partitioning in gradients of tropical land-use intensity and tree species diversity**

TEAM: Principal Investigators: Christoph Leuschner, Martyna Kotowska (UGoe); Triadiati Antono (IPB University).
Scientific Staff: Sasya Samhita (Doctoral Researcher, UGoe).
Field Assistants: Jamaluddinsyah, Melky Susandro; Fajar Septiawan; Amanatun Nisa, Syahbarudin

Picture 6. a) Minirhizotron scanning in the BEE plots, **b)** Extracting roots using soil corers, **c)** Root tracing of oil palms to measure species-specific root traits.

RESEARCH SUMMARY:

The conversion of tropical rainforests to oil palm plantations has led to a decline in biodiversity and ecological functionality. As a potential solution to mitigate the adverse effects the biodiversity enrichment experiment (EFForTS-BEE) was conducted by planting six native tree species in oil palm plantations with varying diversity levels and plot sizes. Our subproject focuses on the belowground component looking at root interactions and their influence on oil palm performance and yield. The objectives include examining the effects of agroforestry zones on root morphology and root growth as well as comparing root resource uptake strategies and testing the best performing tree species-oil palm combination. Simultaneously, we also aim at linking belowground and aboveground functional trait diversity and assessing the importance of functional diversity for plant productivity across different land-use systems. To examine the functional characteristics of fine roots and their assemblage within the ecosystem, a **species-specific root traits** measurement campaign was conducted for 78 tree species in the biodiversity enrichment experiment (EFForTS-BEE) and 65 species in the core plots of different land-use systems. To estimate the **fine root production** and to determine patterns of coexistence, competition, and drivers of species interactions in belowground assemblages, we have installed 162 ingrowth cores in the EFForTS-BEE and root growth was measured after 12 months (Fig. 7). To estimate **fine root biomass**, we conducted a fine root

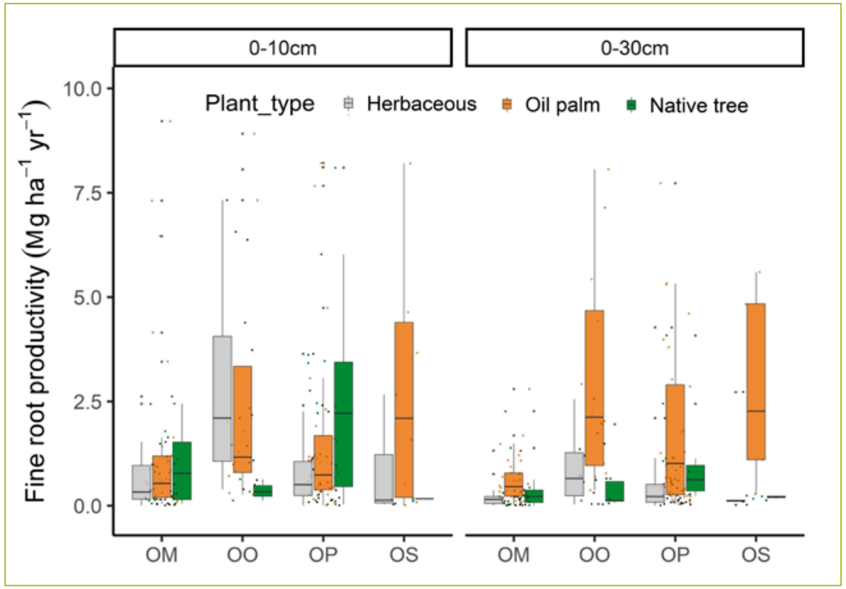


Figure 7. Preliminary result of fine root productivity (Mg ha^{-1} yr^{-1}) in the EFForTS-BEE oil palm enrichment plantations using ingrowth cores. Shown are four different species combination of diversity level one namely: oil palm & mixed tree species (OM), oil palm & oil palm (OO), oil palm & *Parkia speciosa* (OP) and oil palm & *Shorea leprosula* (OS). Different coloration of the boxes denotes the roots of different plant types – native tree, oil palm and herbaceous roots.

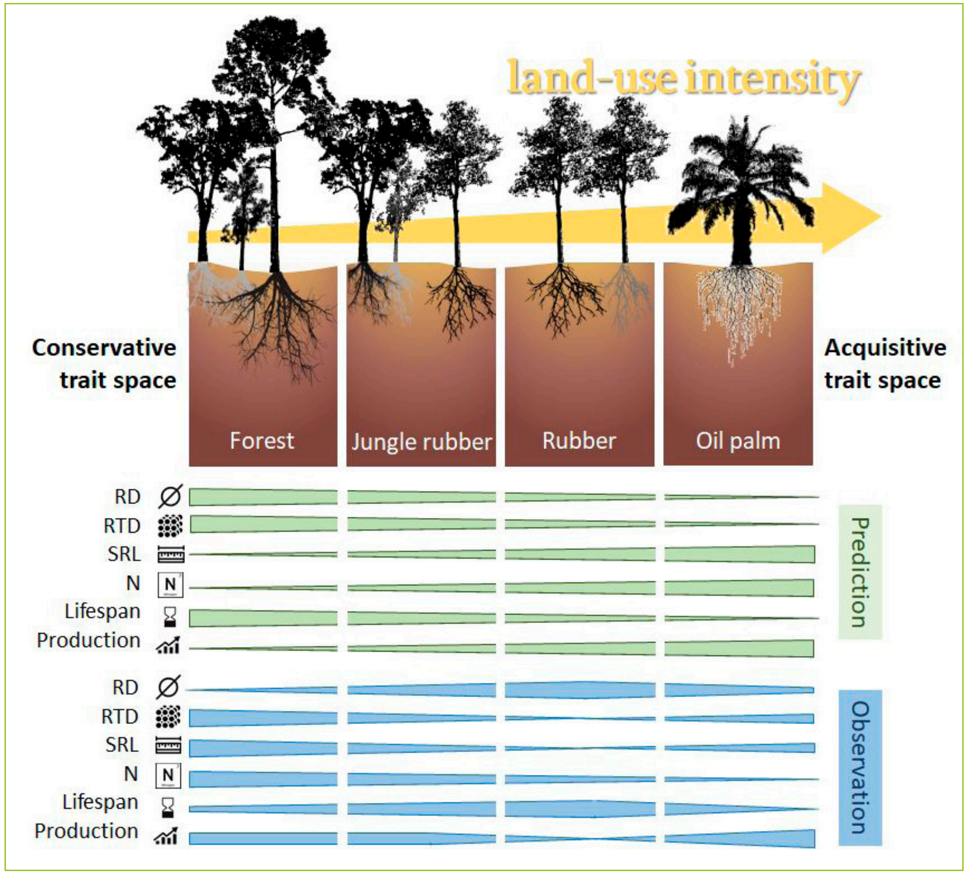


Figure 8. Graphical summary of predicted and observed changes in fine root dynamics (lifespan and production) and root functional traits (RD = root diameter, RTD = root tissue density, SRL = specific root lengths, N = nitrogen content) with forest conversion to plantations based on samples from 32 EFForTS core plots.

inventory on all 52 sites where existing roots from undisturbed soil were extracted, sorted, and weighed (Fig. 8). Additionally, we have installed and scanned 90 mini-rhizotrons to determine **root dynamics** with birth, death and turnover rates and compare the results to the outcomes of the ingrowth core study. Further, for understanding **root water uptake**, root competition intensity and the degree of asymmetry between oil palms and planted trees, we plan to measure **sap flux** using miniature sap flow gauges on exposed roots of competing oil palms and native planted tree species both in moist and drier periods.

Using data collected jointly with B06 and B14 within the *Landscape Assessment campaign* we are working on understanding the influence of land-use intensity on **plant biomass and productivity** and how to upscale the results combining remote sensing and satellite data. Functional trait data collected on all tree species will be used to access the changes in **functional diversity** with forest transformation to monoculture plantations.

B06

TITLE: **Taxonomic, functional, phylogenetic, and biogeographical diversity of vascular plants in rainforest transformation systems on Sumatra (Indonesia)**

TEAM: Principal Investigators: Holger Kreft (UGoe); Sri Sudarmiyati Tjitrosoedirdjo (IPB University, SEAMEO-BIOTROP).
Scientific Staff: Fabian Brambach (Postdoctoral Researcher, UGoe).
Associated Scientists: Nathaly Rokssana Guerrero Ramírez (Postdoctoral Researcher, UGoe), Yayan Wahyu C. Kusuma (Postdoctoral Researcher, BRIN), Wendy A. Mustaqim (Universitas Samudra, Langsa, Aceh).
Field and lab assistants: Edo Mauliarta, Dian Muh Fauzan, Mei Linda Mardalena, Widya Sari.

Picture 7. A tiny fraction of Sumatra's stunning plant diversity, all found in Harapan rainforest.

RESEARCH SUMMARY:

Plants as main primary producers and structural components are essential for resilient terrestrial ecosystems while providing manifold contributions to humans. The focus of subproject *B06 Kreft* is to understand changes in different dimensions of plant diversity from local to landscape scales. Results will contribute to solid assessments of economic-ecological trade-offs and the development of science-based solutions for sustainable land-use and biodiversity conservation.

Our main activities in the past year continued to be with the *EFForTS Landscape Assessment (LA)*. Fabian Brambach is leading a synthesis paper showcasing the *LA* as a proof of concept for landscape-scale assessments of biodiversity and ecological and socioeconomic functions in a tropical mosaic landscape. A key component for the upscaling of biodiversity and ecological functions measured in the plots to landscape scale are potential links between these metrics and vegetation structure. BO6 conducted mobile lidar scans to derive vegetation structural metrics for all LA plots (see Fig. 9 for examples of 3D point clouds from lidar). The ongoing MSc thesis of Sarah Kabache shows that, while there is large heterogeneity in most metrics, a clear relationship between land-use and vegetation structure can be observed (Fig. 10). The synthesis paper will further explore how these structural differences act on biodiversity patterns of selected taxa and functions.

LA data of tree functional traits measured in the field are being analysed (with B04) and initial results suggest that functional land-use change is leading to a shift in trees' strategies

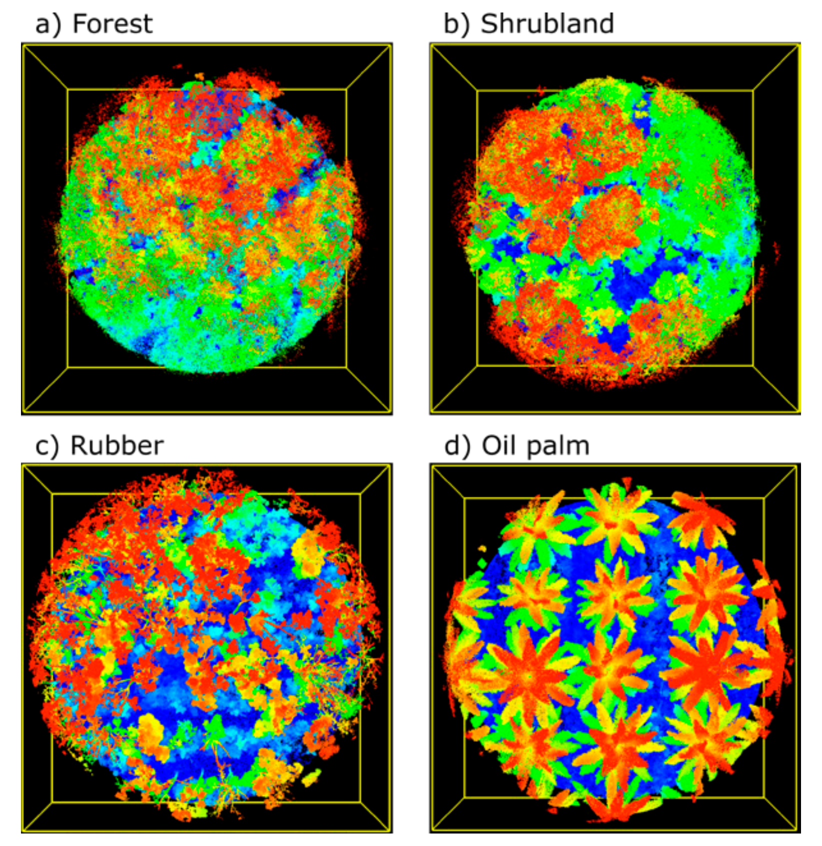


Figure 9. Mobile-lidar-derived 3D point clouds of exemplary LA plots showing the contrasting structural features in four different vegetation types. Point clouds processed with CloudCompare and Lidar360.

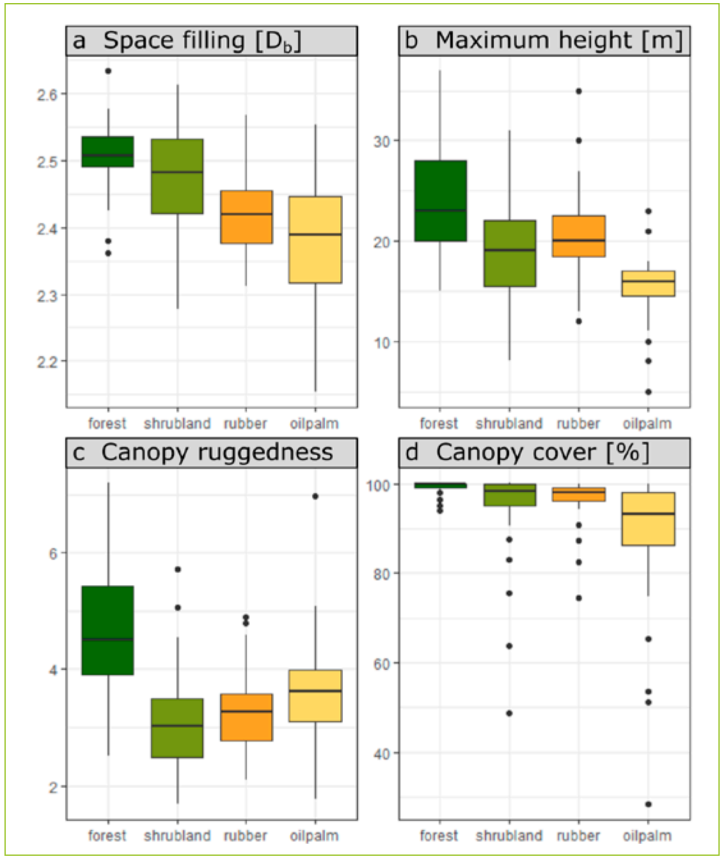


Figure 10. Land-use transformation leads to changes in vegetation structural properties: Lidar-derived measures from 128 LA plots in forest, shrubland, rubber plantation and oil palm plantation. **a)** Space filling expressed as box dimension (Db), **b)** maximum plant height per plot, **c)** Canopy ruggedness, expressed as Rumple index, and d) canopy cover in percent.

and a reduction in functional diversity. To uncover such shifts in detail, correct identification of plant specie is necessary. Correctly identifying species of a hyperdiverse and understudied flora like that of Sumatra is a daunting task but the combination of morphological characters and DNA barcoding, carried out jointly by B06 and B14, creates important synergies to speed up the process. Images of all plants collected by B06 and collaborators are currently entered into an image database hosted at BIOTROP Bogor which will be made available online. In addition, together with B06 associated researcher Wendy A. Mustaqim, we are working on the compilation of a list of alien plant species of Sumatra to close the knowledge gap impeding precise analyses of alien plants on the island.

B06 also carried out inventories of tree regeneration and understorey vegetation in EFForTS-BEE, including the measurement of functional traits (with B11) and a re-inventory of trees in the Core Plots that will enable us to estimate species turnover, mortality and productivity in different land-uses.

B08

TITLE: **Structure and functioning of the decomposer system in tropical lowland rainforest transformation systems**

TEAM: Principal Investigators: Stefan Scheu (UGoe); Rahayu Widyastuti (IPB University).
Scientific Staff: Ting-Wen (Tim) Chen, Valentyna Krashevska (Postdoctoral Researcher, UGoe).
Associated Scientists: Simin Wang, Zheng Zhou (Doctoral Researchers, UGoe), Garvin Schulz, Winda Ika Susanti (Postdoctoral Researchers, UGoe), Anton Potapov (Postdoctoral Researcher, iDiv Leipzig).

RESEARCH SUMMARY:

Subproject B08 is dedicated to studying the diversity of animals and microorganisms in the soil, exploring their interactions within soil food webs, and investigating the important roles they play in ecosystem functions, such as the decomposition of litter. Since the last year of the third phase of the project, we showed among others that (1) land use changes intensify seasonal variations in belowground food webs, particularly affecting microbial communities, leading to amplified fluctuations in vital ecosystem functions like nutrient cycling and carbon sequestration, which could potentially jeopardize the long-term stability of tropical ecosystems (Fig. 11), (2) the conversion of rainforests to plantations leads to significant changes in energy flow and function in arthropod food webs, and (3) litter microorganisms in tropical forests heavily rely on root resources, whereas microbial communities in soil are structured by long-term factors such as land-use type. Currently, we have all samples from the EFForTS long-term experiments and platforms, including OPMX and BEE and the Landscape Assessment. The samples are currently being sorted, soil arthropods are being determined, and litter and soil DNA is being extracted to explore microbial food webs.

Picture 8. from left to right: Anton Potapov, Leonarda Situmorang, Valentyna Krashevska

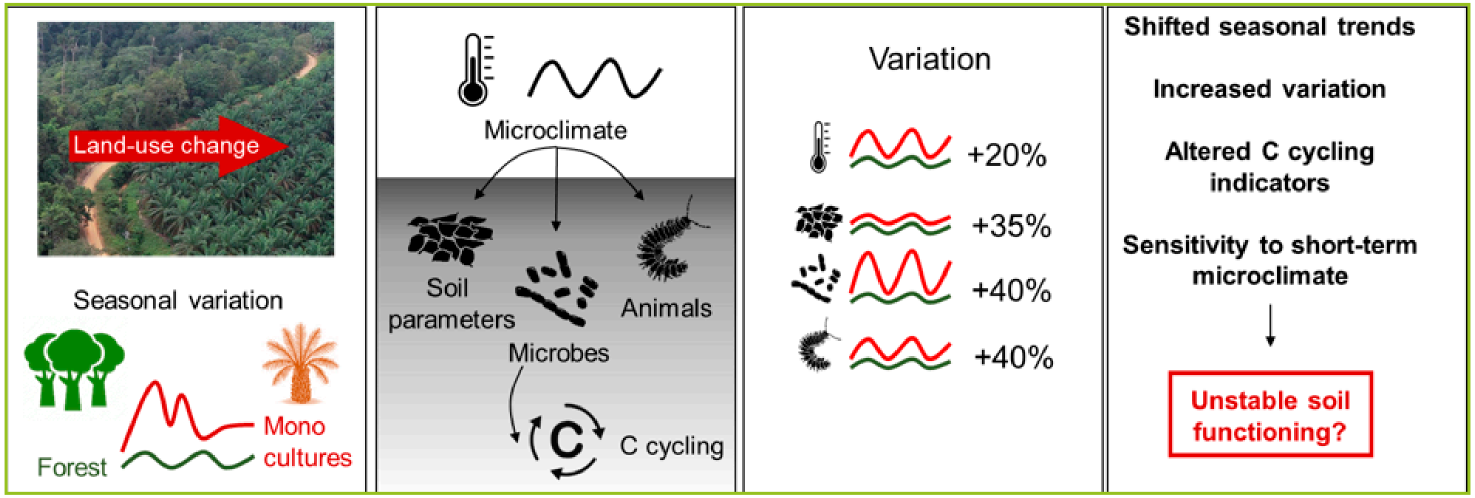


Figure 11. Land-use change shifts and magnifies seasonal variations of the decomposer system.

B09

TITLE: **Aboveground biodiversity patterns and processes across rainforest transformation landscapes**

TEAM: Principal Investigators: Catrin Westphal (UGoe); Ingo Grass (University of Hohenheim); Damayanti Buchori, Yeni Mulyani, Windra Priawandiputra, Ellena Yusti (IPB University); Fuad Nurdiansyah (UNJA).

Scientific Staff: Arne Wenzel (Postdoctoral Researcher, UGoe).

Associated Scientist: Kevin Darras (Postdoctoral Researcher, TU Dresden).

Field team: Patrick Diaz, Erick Mandelson, Ilham, Sugeng Selviandi, Davig Warisman.

RESEARCH SUMMARY:

In subproject B09, our focus is on studying aboveground biodiversity and its impact on ecosystem functions. In 2022, our research activities primarily centered around colonies of the stingless bee *Tetragonula laeviceps*. Leveraging the EFForTS-landscape assessment platform, our dedicated B09 field team successfully established three colonies across a total of 80 plots. Over a span of six months until November 2022, we monitored the colonies' development, foraging behavior, and survival rates to examine how landscape heterogeneity influences their performance. Additionally, we collected pollen, honey, and resin samples. In an exciting collaboration

Picture 9. Deborah and Irene are waiting for bees to return to their hive during the release and recapture experiment in EFForTS-BEE (a). Angelina and Davig during a beat sample in EFForTS-BEE (b). The B09 field team during a field trip (from left to right: Laura, Angelina, Ellena, Erick, Ilham, Patrrck) (c). Ilham and Ellena during the retrieval of an audiomoth – a sound recorder to detect bats (d).

with A01 and B11, we are currently employing morphological and metabarcoding techniques to identify the pollen samples.In early 2023, we expanded our investigation by also introducing Stingless bee colonies into the EFForTS-BEE plots. This endeavor aims to explore how tree islands impact the survival and performance of native pollinators. The project, which will conclude in July 2023.

Furthermore, at the EFForTS lab in Jambi, our assistant Febrina Herawani is nearing completion of the identification process for arthropods sampled in the EFForTS-OPMX via pantraps in the past years. Once finished, we will possess a valuable timeline of data on flower-visiting insects in EFForTS-OPMX from 2016 to 2021. Together with experts, we are also currently in the process of finalizing the bat and bird data that have been collected in 2021.

Our postdoctoral researcher Arne Wenzel has spearheaded a large synthesis project using the data on oil palm cultivation gathered during phases one and two. This comprehensive project has recently been submitted (please refer to focus 1 for further details). Additionally, while overseeing the Landscape Assessment, Arne continues to coordinate various activities. He organizes regular meetings and workshops, fostering collaboration and promoting communication among project members involved in the Landscape Assessment.

Regarding BSc and MSc projects, we hosted two MSc students, Angelina Stockinger and Laura Störzer, who conducted a length field stay at EFForTS-BEE starting in November 2022. During their time, they focused on measuring predation rates using dummy caterpillars, monitoring bat activity using sound recorders, and assessing the diversity of arthropods inhabiting the understory vegetation through beat samples. They have recently returned to Germany and are currently in the process of analyzing their collected data.

B10

TITLE: **Landscape-level assessment of ecological and socio-economic functions of rainforest transformation systems**

TEAM: Principal Investigators: Kerstin Wiegand (UGoe); Jann Lay (GIGA Hamburg); Surya Tarigan (IPB University).

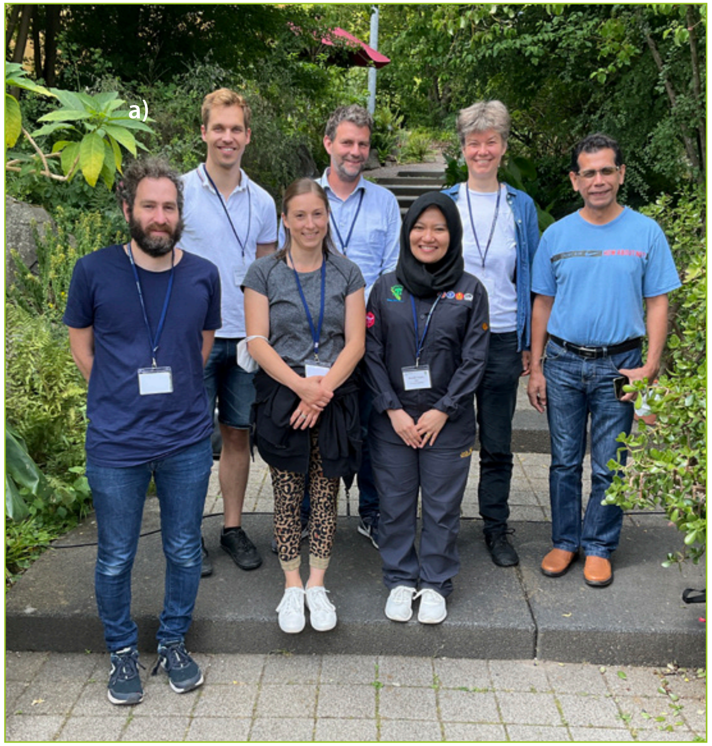
Scientific Staff: Sebastian Fiedler (Postdoctoral Researcher, UGoe), Julia Henzler (Doctoral Researcher, UGoe).

Associated Scientist: Craig Simpkins (Postdoctoral Researcher, New Zealand), Eyal Goldstein (Doctoral Researcher, UGoe).

RESEARCH SUMMARY:

In project B10, we integrated the knowledge from the abiotic (A groups), biotic (B groups), and human (C groups) perspectives to assess ecological and socio-economic functions of rainforest transformation systems in Sumatra using EFForTS-ABM, an economic-ecological land-use change simulation model.

EFForTS-ABM has been successfully developed (Dislich *et al.* 2018) and was extended by further socio-economic and ecological processes in Phase 3 of EFForTS. EFForTS-ABM is an agent-based and spatially-explicit simulation model where individual households (agents) own agricultural fields (oil palm and rubber) within a forested landscape (Fig. 12, Dislich *et al.* 2018). These households take



Picture 10. Team of B10 during the retreat in Volpriehausen in July 2022.

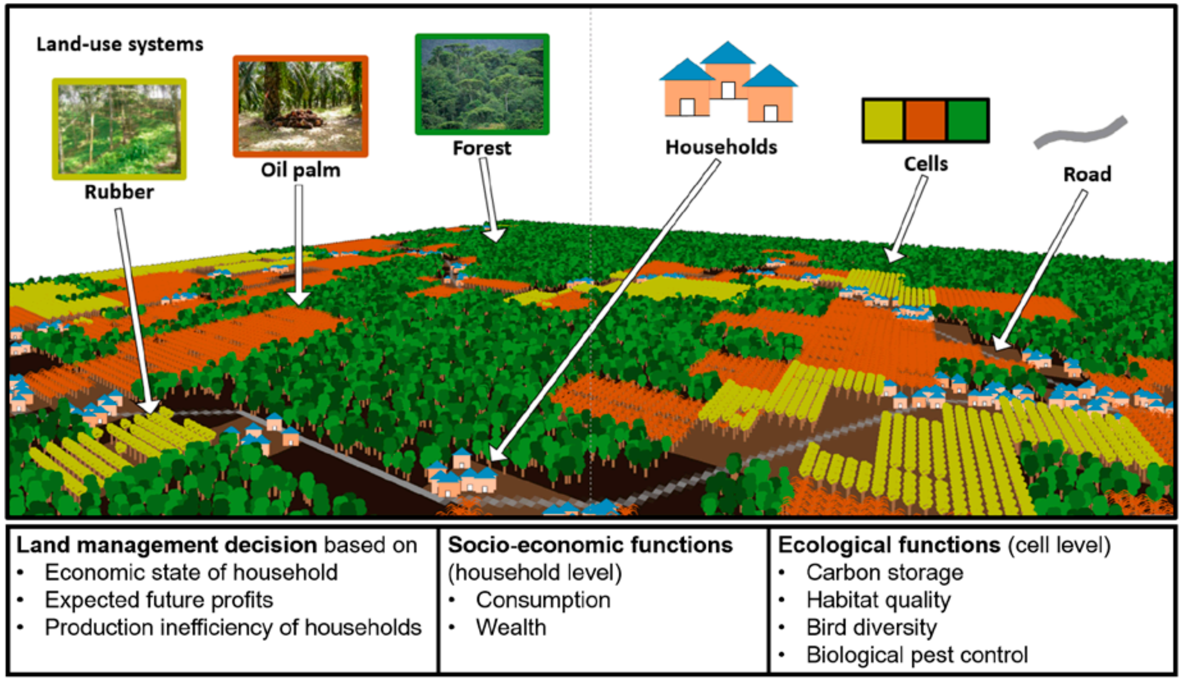


Figure 12. Overview of the agent-based land-use change model EFForTS-ABM.

rational land-use management decisions with the aim to maximize their economic returns but with consequences for ecological functions. In Phase 3, we expanded the socio-economic functions to better represent the land market and we added further ecological functions and biodiversity indicators (i. e., habitat quality, carbon storage, bird diversity, biological pest control) based on ecological data that was available early on in Phase 3 of EFForTS. Currently, we are adding additional processes directly into EFForTS-ABM (i. e., water processes, understory plant diversity and arthropod diversity) based on empirical knowledge from EFForTS. In collaboration with subproject C08 of EFForTS, we are currently reviewing the literature on payments for ecosystem services (PES) in ABMs (N. Halmschlag, unpubl. data, MSc thesis in progress) as a basis for developing model rules for implementation of PES into EFForTS-ABM. EFForTS-ABM is a key tool to assess, amongst others, the effects of different landscape designs, smallholder household characteristics, with the overarching goal to identify characteristics of policy measures that lead to landscapes where ecological benefits are maximized and socio-economic costs minimized.

Using EFForTS-ABM, we assessed the effects of different landscape structures (Fig. 13) generated by EFForTS-LGraf, a process-based landscape generator also developed within EFForTS (Salecker *et al.* 2019), quantified by R package *landscapemetrics* that calculates landscape metrics (Hesselbarth *et al.* 2019), on habitat quality, biological pest control and bird diversity (C. Wiewelhove, unpubl. data, BSc thesis; R. Groninga, unpubl. data, MSc thesis. T. Koller, unpubl. data, BSc thesis). It was shown that an increase in agricultural area in the landscape had no effect on biological pest control and a negative effect on alpha bird diversity (Fig. 13b), but a positive effect on beta bird diversity (not shown). Greater proportions of oil palm plantation area in the landscape affected biological pest control (Fig. 13b) as well as alpha (Fig. 13b) and beta bird diversity (not shown) in complex ways. Larger field sizes, a measure for landscape fragmentation, positively affected biological pest control but did not affect alpha bird richness (Fig. 13b). Landscape-level habitat quality was found to be negatively affected by landscape fragmentation (not shown). These results reveal different behaviors of functions with changes in the landscape structure, indicating the existence of trade-offs among functions.

In addition to EFForTS-ABM, we finalized the R package *spectre* (Simpkins *et al.*, 2022) that allows us to predict species distributions on a wider spatial scale based on the knowledge from single field sites.

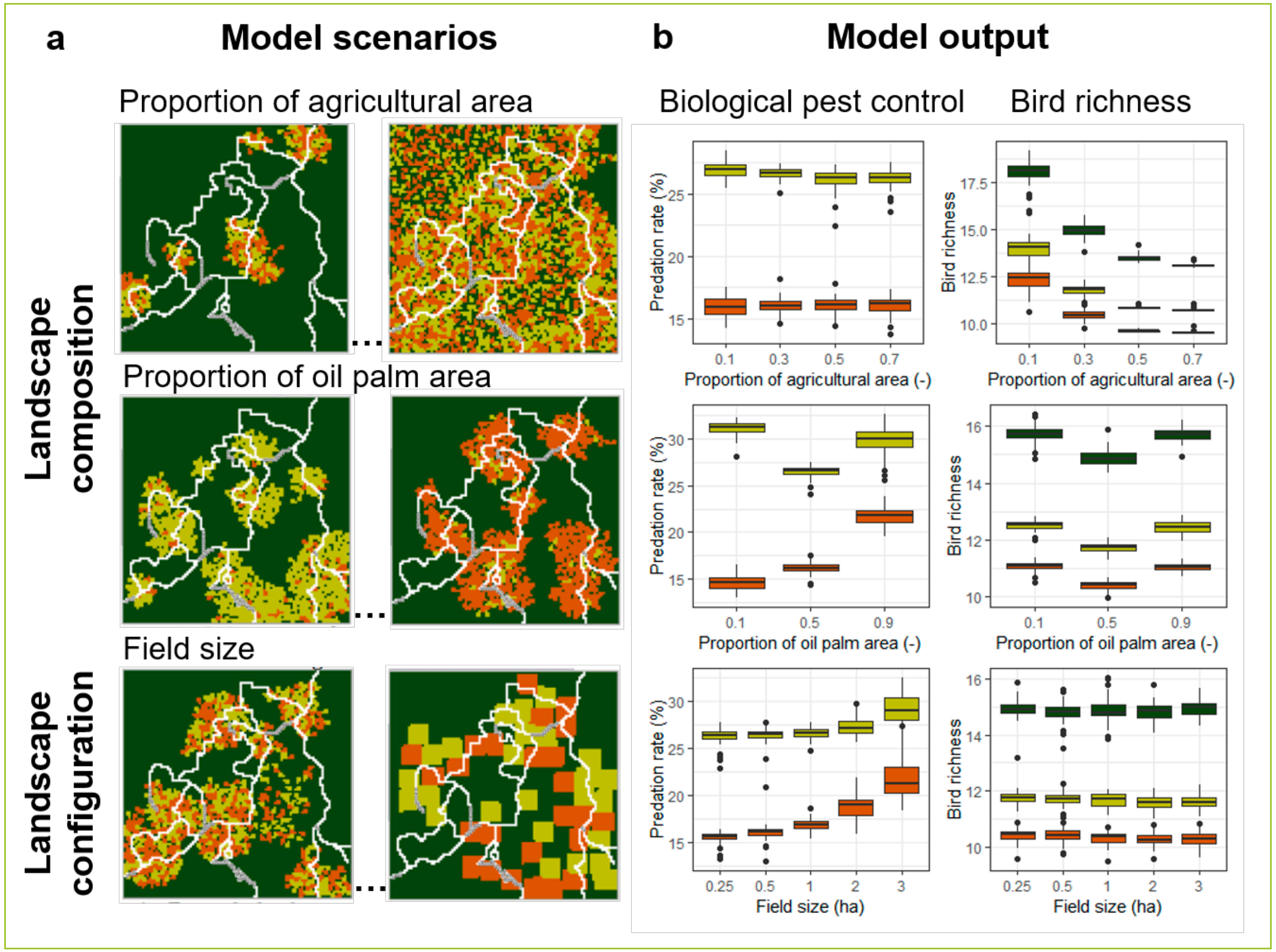


Figure 13. EFForTS-ABM scenarios on the effect of landscape composition and configuration on ecological functions and biodiversity. (a) Example scenario maps generated by EFForTS-LGraf as input for EFForTS-ABM to study the effect of landscape composition and configuration (forest = green, oil palm = orange, rubber = yellow) on (b) biological pest control and bird richness (alpha diversity).

B14

TITLE: **The use of DNA barcoding to assess landscape effects on phylogenetic and functional diversity**

TEAM: Principal Investigators: Oliver Gailing (UGoe); Iskandar Z. Siregar (IPB University); Bambang Irawan (UNJA).
Scientific Staff: Carina Carneiro de Melo Moura (Postdoctoral Researcher, UGoe).
Associated Scientists: Ulfah Juniarti Siregar, Fifi Gus Dwiyanti (IPB University); Essy Harnelly (UNSYIAH); Sri Rahayu (KRB LIPI).

RESEARCH SUMMARY:

Insights on root-fungal association in forest conversion systems

Root-fungal associations play a crucial role in ecological processes, such as nutrient uptake regulation and plant-plant interactions. The underlying factors driving these associations in natural and human-modified tropical landscapes remain uncertain. Our ongoing efforts aim to identify selective connections between roots and fungal communities and determine which plant roots and fungal taxa exhibit non-random associations with specific land use systems along a gradient of forest conversion by integrating roots (B14) and fungi (B07) data from core plots. Our results revealed a strong modular structure in the root-fungi network analysis, with distinct clusters formed by operational taxonomic units (OUTs) assigned to oil palm and herbal species. Interestingly, this included non-native species such as *Asystasia gangetica* and *Clidemia hirta*. Furthermore, we observed that highly connected nodes, which played important roles as connectors or kinship, were occupied by generalist or opportunistic species from both the plant and fungal kingdoms. These species were also identified as potential indicators of disturbed environments, highlighting their adaptability and association with altered ecological conditions (Fig. 14).

A glimpse at plant diversity (roots and litter) – preliminary overview from the landscape assessment

The B14 subproject has a goal to examine whether plant diversity can be consistently estimated in different layers of the forest, including below ground (roots), litter, and above ground (trees, shrubs, and herbs), using molecular-based surveys. The following steps will then explore how plant diversity affects the diversity of other trophic groups (i. e., nematode, fungi, bacteria, etc.). Initial assessments have already revealed significant diversity differences among land use systems in both roots and litter (see Fig. 15 A, B). Moving forward, there will be a close collaboration with colleagues from B08, B06, B10 subprojects, and other researchers in the coming months.

Ultimately, our plans in the framework of the Landscape Assessment include a DNA-based plant inventory to infer phylogenetic and functional diversity in the different land-use types and to obtain results with a focus on network interactions between plants and associated groups at the above and below-ground levels.

Moreover, the researchers from B14 and B09, along with associated colleagues, are currently investigating the changes in pollen diversity throughout different seasons. In the context of our EFForTS project, there are ongoing efforts to identify viral loads and other types of microbiota present in pollen samples. Additionally, the B14 subproject is analyzing roots and scat samples from BEE using DNA barcoding and metabarcoding techniques, with continuous collaboration with the subproject B11. The support of B14 assistants (Nando, Nadia, Sari, other temporary assistants) (Picture 11) and administrative staff (Barbara Wick, Aiyen Tjoa, Megawati) is very much appreciated by the B14 team. Special acknowledgement goes to lab technicians Gudrun Diederich, Larissa Kunz, and Alexandra Dolynska.

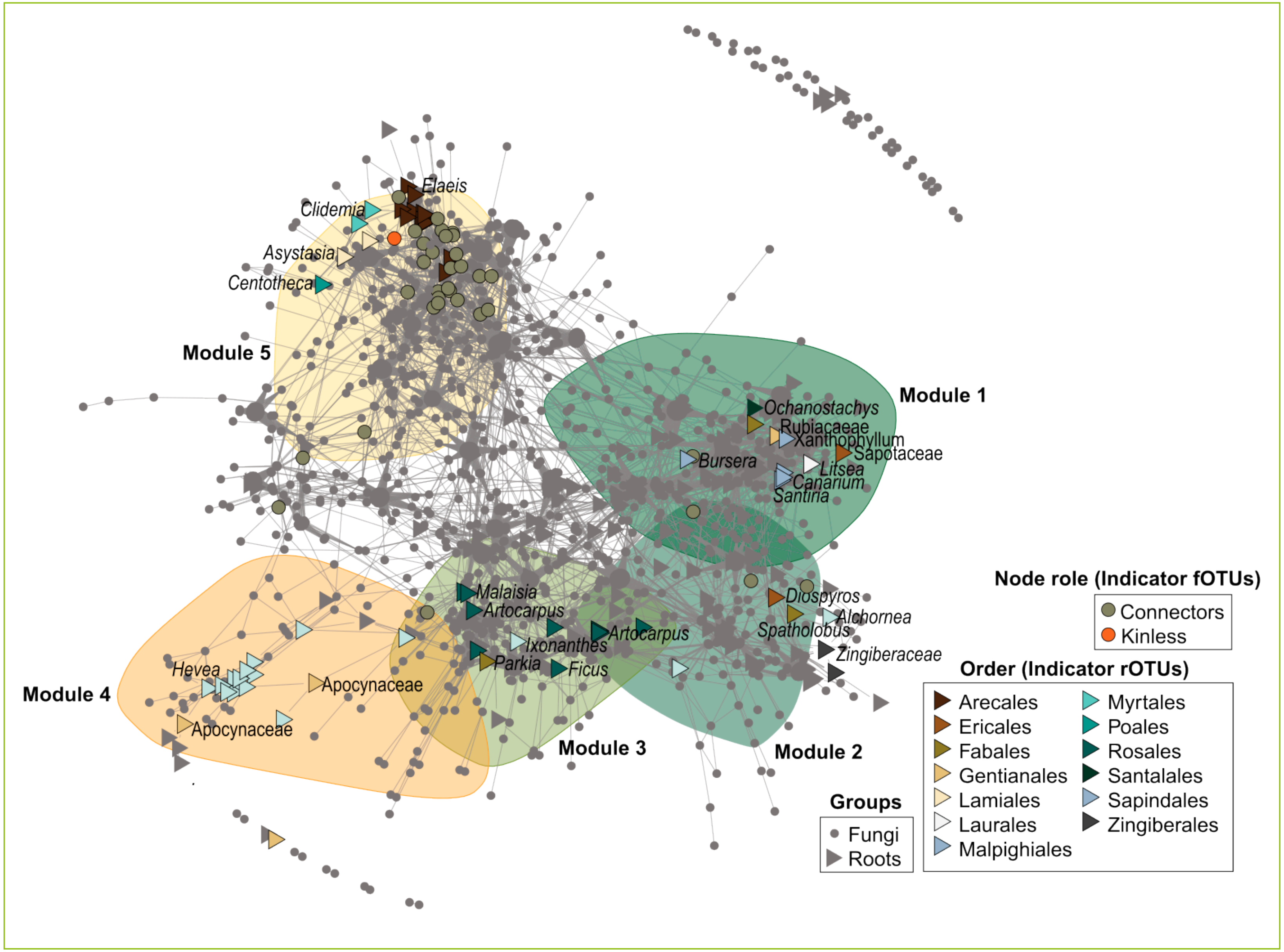


Figure 14. Multi-kingdom network based on significant co-occurrence correlations between roots and fungi. Modules displayed highlight clusters containing indicator Operational Taxonomic Units (OTUs) assigned to plants using the modularity analysis by simulated annealing. Indicator groups are presented at the genus or family level. Moura *et al.* 2023 (in prep).

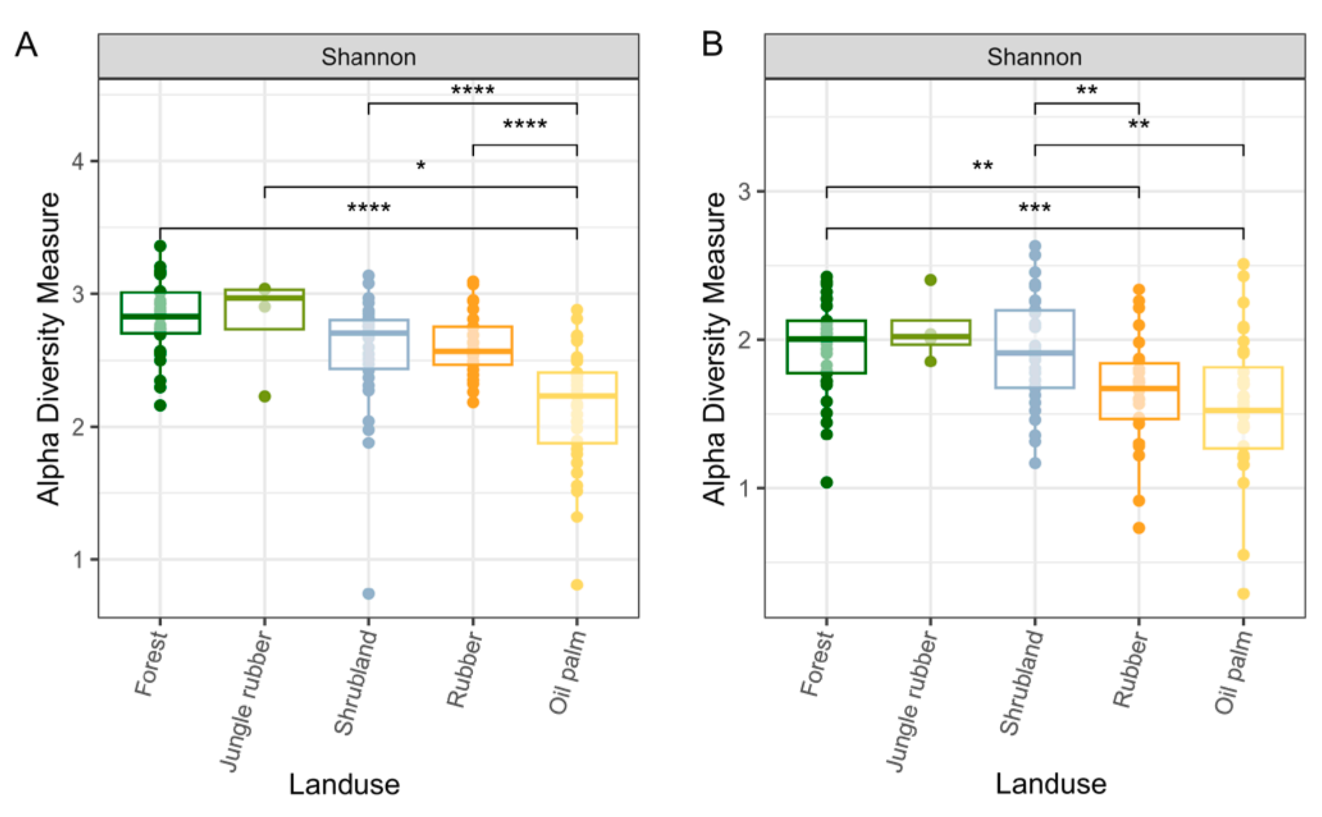


Figure 15. Diversity of plant Operational Taxonomic Units (OTUs) detected in roots **(A)** and litter **(B)** samples collected in the Landscape Assessment.

Picture 11. a) we see the field assistants from B14 in the midst of their training. From left to right, we have Nando Gafar, Nadia Anggraini, Sari Widia, and Anoem Gafar.
b) Nando can be seen collecting samples of roots and litter on the field during landscape assessment sampling campaign.

Group C

FIELDS OF RESEARCH

- Human dimensions

GROUP COORDINATORS

- Meike Wollni, Oliver Mußhoff (UGoe);
- Nunung Nuryartono (IPB University);
- Rosyani (UNJA)

C01

TITLE: **Smallholder productivity, market access, and international linkages in rubber and palm oil production in Jambi Province**

TEAM: Principal Investigators: Bernhard Brümmer (UGoe); Dedi Budiman Hakim (IPB University), Zulkifli Alamsyah, Mirawati Yanita (UNJA). Scientific Staff: Gabriela Carbajo Alvarez (Doctoral Researcher).

RESEARCH SUMMARY:

Data collection in Costa Rica

A joined data collection with C07 & C08 took place during October 2022 – January 2023, a comprehensive questionnaire was applied to 517 oil palm smallholders gathering information on households, farm, and institutional characteristics in the region of Punta Arenas (>65% of total oil palm production) in Costa Rica.

Determinants of yield gap and the burden of debt in smallholder oil palm productivity

With the data collected in Costa Rica, our ongoing research examines the components of the yield gap in oil palm smallholders. Smallholder plots are, on average, around three times bigger than in Indonesia, but livelihoods are very similar. Likewise, the yield gap between smallholders and agro-industrial companies is around 40%. By analysing the pro-

Picture 12. Collecting data while corona restrictions were still ongoing was a big challenge, however I got all the support I needed from the project to make it happen (Gabriela, 2nd from right and team in Costa Rica).

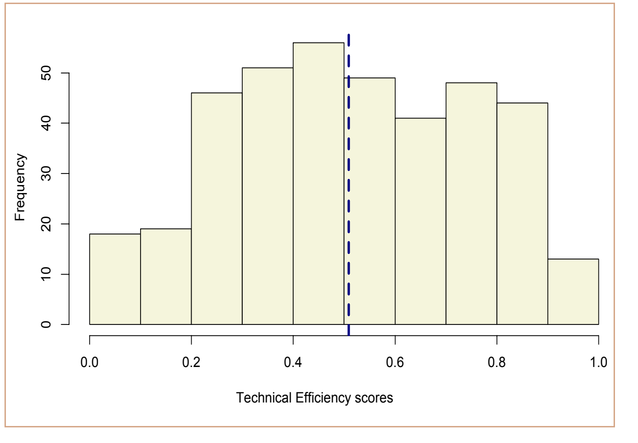


Figure 16. Histogram of Technical Efficiency scores of Costa Rican oil palm smallholders

duction technology, we found that small producers in Costa Rica are operating under increasing returns to scale, which means that an increase in the number of inputs or production factors will lead to an even higher increase in output. Moreover, a prominent pest, "*flecha seca*", was a shifter in production as farmers with sick trees reduced their production by 9%, on average. In addition, smallholders in Costa Rica have an efficiency of 50% (Fig. 16), meaning that they could increase their productivity levels by using the same quantity of inputs and technology by around 50%.
Preliminary results are consistent with the literature: the most critical drivers for reducing technical inefficiency are landownership, being part of a cooperative or association, and receiving technical assistance while having an agricultural burden debt has the opposite effect.

C02

TITLE: **Social transformation processes and sustainable resource use in rural Jambi**

TEAM: Principal Investigators: Heiko Faust (UGoe); Endriatmo Soetarto, Soeryo Adiwibowo, Rina Mardiana (IPB University); Rosyani (UNJA).
Scientific Staff: Thi Nhung Pham (Postdoctoral Researcher, UGoe), Maike Buckemüller (Master student, UGoe), Franziska Halbach (Master student, UGoe).
Associated Scientists: Jonas Hein (IDOS Bonn); Yvonne Kunz (KITLV Den Haag).

RESEARCH SUMMARY:

Since the last newsletter (no. 8, 2022) the German-Indonesian research team of C02 concentrated on two activities: 1. Syntheses publications, 2. Empirical Master theses.

The first synthesis concentrates on the qualitative social science studies of C02 during the last decade. Overall the publications provide a framework for understanding political changes, land use and land tenure changes, as well as environmental changes (Thi *et al.* in progress). The synthesis shows that political regimes often disregard local perspectives, local culture, and the demands for land tenure formalization. Legitimation often concentrates in various state authorities, resulting in overlapping and contradictive regulations. Thus, land conflicts can only be solved by reallocating land use rights to local actors and respecting local sovereignty. In the context of multi-layer land conflicts, as in Jambi, the implementation of global environmental initiatives mainly exacerbates existing conflicts and contributes to environmental degradation instead of achieving their intended goals. Also, well-intentioned nature conservation programs can end up in a negative impact, when ignoring local reality. Good local land governance is seen as basis for good global environmental governance.
The second study is a more abstract synthesis paper which explores the spatial dimension of the contested renegotiation of society-nature relations in the context of the oil palm boom in Indonesia (Brad and Hein 2022). Drawing on concepts of political ecology, materialist state theory and literature on the transnationalization of the state, it argues that conflicts in the context of the oil palm boom cannot merely be conceptualized as local negotiation processes for access to land, but are increasingly transnational in character. To illustrate how these transnational mechanisms of contestation and conflict resolution operate, the empirical focus lies on conflicts over land in the research region. By drawing our attention to the differentiated strategic selectivities that exist at each level with particular implications for the direction of conflict resolution, we demon-

Picture 13. Franziska Halbach doing a focus group discussion in Pematang Kabau

strate that the perspective of materialist state theory can help inform strategies of resistance by subaltern groups and NGOs.

The first Master thesis deals with "Sustainability perceptions and intra-household capabilities for transformation in rural Jambi: the case of Pematang Kabau" (Halbach, in progress). The objective of this work is to capture individual perceptions of sustainability and opportunities for environmental change. The results show that the understanding of the concept of sustainability is limited. However, environmental changes are clearly identified, such as increasing drought, changes in land use, and loss of soil fertility. Adaptations are seen in sustainable economies, in careful resource management and especially in education. Social cohesion and cultural values are also of great importance.

The second master thesis focuses on "Oil palm cultivation and intra-household gender roles in rural Jambi" (Buckemüller, in progress). Few studies examine the ongoing land use change in terms of its gendered impacts. The emerging debate focuses on factors such as access and control over land, participation in decision-making, employment, wages, and time allocation, and generally results in a pessimistic assessment in terms of potential positive impacts for women's roles. The approach of this investigation is to follow up on this in order to contribute in the form of a case study to close the research gap described above and to put the women's perspective in the foreground. The investigation of the different gender roles will help to better understand the role of women and thus to assess what are the advantages and disadvantages for the development of a sustainable village.

C06

TITLE: **Understanding the certification and replanting behavior of Indonesian smallholder farmers.**

TEAM: Principal Investigators: Oliver Mußhoff (UGoe); Dompak Napitupulu (UNJA).
Scientific Staff: Dienda Hendrawan (Doctoral Researcher, UGoe).
Associated Scientist: Charlotte Reich (Doctoral Researcher, UGoe).

RESEARCH SUMMARY:

During Phase 3, C06 conducted two successful rounds of data collection. The first data collection ran in autumn of 2021 and consisted of 500 smallholders. Here, we employed two discrete choice experiments (DCE) to elicit farmers' preferences for certification schemes and replanting subsidy schemes, which would encourage farmers' participation. Within the context of adopting a certificate, the provision of cash premiums and continuous farm management trainings are statistically significantly driving farmers' adoption decisions. Within the context of replanting, we revealed that smallholders prefer to join a replanting subsidy program and are more attracted when the amount of subsidy offered is greater, they are able to replant gradually, and the registration is group-based instead of individually. In addition, we were also able to illustrate that smallholders are willing to diversify their oil palm plantations if the subsidy amount is increased. With this study, we provided an empirical evidence that policy intervention such as subsidies could imply more than supporting smallholders financially to replant solely, but also as a support to make changes or improvements towards a more sustainable oil palm cultivation. Both results from the certification and replanting DCEs were presented at the American Agricultural Economics Association Conference in July 2022.

Table 1. Coller-Williams task with framing.

Session	Receive money in 1 week from middleman	Receive money in 4 weeks from mill/ cooperative	I choose
1	100,000	100,600	1 week ----- 4 weeks
2	100,000	101,200	1 week ----- 4 weeks
3	100,000	101,700	1 week ----- 4 weeks
4	100,000	102,300	1 week ----- 4 weeks
5	100,000	102,900	1 week ----- 4 weeks
6	100,000	103,500	1 week ----- 4 weeks
7	100,000	104,100	1 week ----- 4 weeks
8	100,000	104,700	1 week ----- 4 weeks
9	100,000	105,300	1 week ----- 4 weeks
10	100,000	105,900	1 week ----- 4 weeks

"Imagine that you want to sell your oil palm harvest. You have two options: 1.) you can sell your harvest to a middleman for faster payment (1 week) but lower amount of cash or 2.) You can sell your harvest to a mill or cooperative for slower payment (4 weeks) but higher amount of cash. You will play two scenarios, with 10 sessions in each scenario. Please circle which option you choose in each session."

The second data collection was conducted from August 2022 until March 2023 and leveraged behavioral insights into farmers' (dis) investment behavior and risk management techniques, as well as the impact of the palm oil export ban on farmers' livelihood. We have several research questions: *Does framing (in economic experiments) affect the time preferences of smallholder farmers? Can cognitive load and financial literacy explain inconsistencies in experimentally measured time preferences? Can financial literacy explain differences in results between self-assessed and experimentally measured risk attitudes? How do financial literacy, cognitive skills, risk attitude, and time preferences affect (dis)investment behavior? What are the drivers and challenges of farmers' intention to adopt diversification in oil palm plantations? How were farmers affected by the export ban on palm oil?* To answer them, we utilized various economic experiments, including investment and (dis)investment experiments, an Eckel-Grossman task, Coller-Williams task, and various socio-demographics and likert-scale items surveys. The overall sample included 400 farmers from Batanghari and Muaro Jambi Districts. While most of our experimental data analysis is still ongoing, descriptive results on diversification challenges show that 32,2% of farmers perceive diversification as difficult, 23,4% are not aware of diversification benefits, and 21,9% perceive a lack of training/ extension to adapt to a non-monoculture system. Regarding our research question on

Picture 14. C06 team conducting interviews and meeting farmers.

the export ban, we were able to highlight, the stark farm gate price deterioration for fresh fruit bunches, which farmers experienced following the export ban and the associated decreased farm profits.

We are grateful for supportive collaboration between the administrative staff in Jambi and particularly our team of enumerators, who enabled this productive third phase of C06.

Picture 15. C06 team conducting interviews and meeting farmers.

C07

TITLE: **Determinants of land-use change and impact on household welfare among rural farm and non-farm households**

TEAM: Principal Investigators: Matin Qaim (ZEF, University of Bonn), Hermanto Siregar (IPB University), Zulkifli Alamsyah, Ummi Kalsum (UNJA).
Scientific Staff: Kibrom T. Sibhatu (Postdoctoral Researcher, UGoe), Jakob Latzko (Doctoral Researcher, UGoe).

RESEARCH SUMMARY:

The C07 project participated in all three phases of the CRC 990, with specific but interlinked research objectives in each phase. In Phase I, we focused on investigating the socioeconomic determinants of land-use changes. In Phase II, we examined the socioeconomic impact of land use change on rural households with a particular focus on the effects of oil palm cultivation. In the final phase, we focus on studying the long-term effects of land use change on farm structural transformation and welfare dynamics in smallholder farm and non-farm households in Jambi.

We conducted three types of household surveys in Jambi, Indonesia: first, a panel survey of 700 farm households in 2012, 2015, and 2018; second, a panel survey of 400 labor households in 2015 and 2018; third, a cross-sectional survey of 300 farm households in 2021 as part of the EFForTS Landscape Assessment Experiment. In addition, we conducted a survey of 500 farm households in Costa Rica in 2022 to also understand oil palm cultivation effects in other parts of the world. We analyzed these survey data with various econometric models.

Picture 16. C07 researchers Jonida Bou Dib and Christoph Kubitza during the household survey in 2015 (Photo: C07)

From the C07 work, so far we published 36 articles in peer-reviewed journals. We also contributed socioeconomic data and analysis to multiple collaborative articles published in high-impact factor interdisciplinary journals. Our data and findings indi-

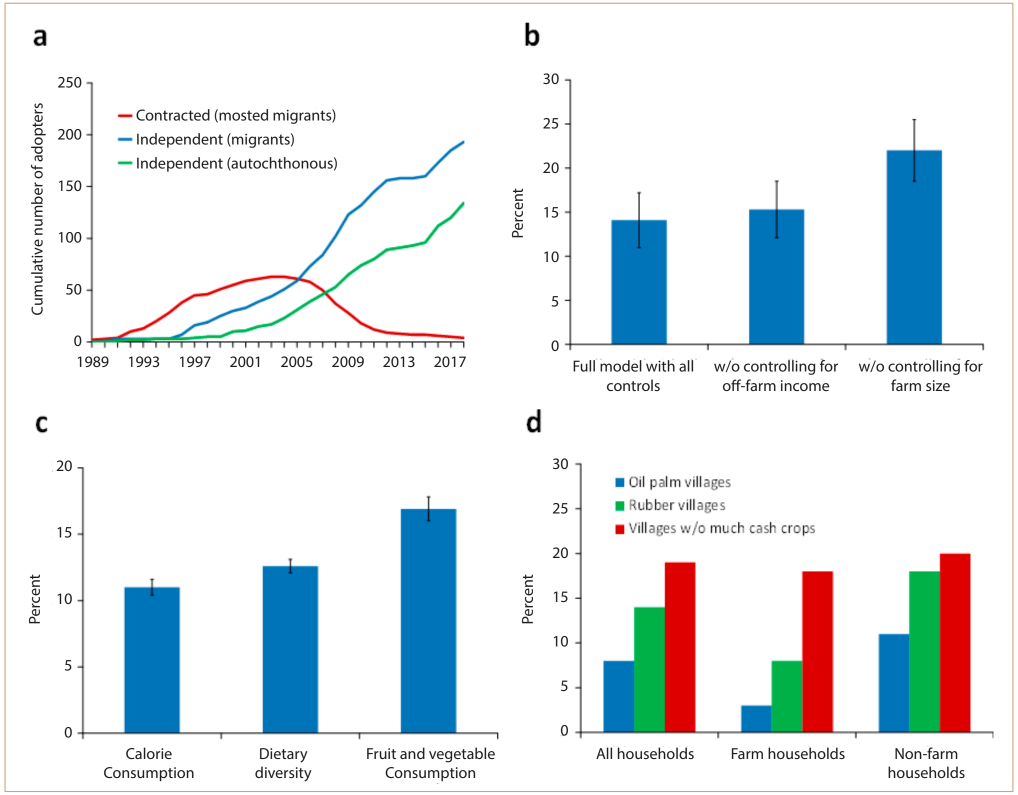


Figure 17. Adoption and socioeconomic impact of oil palm cultivation in Jambi Province, Indonesia. (a) Oil palm adoption in a random sample of 700 farm households. (b) Effect of oil palm cultivation on household consumption expenditure (with standard error bars). (c) Treatment effects of oil palm cultivation on household diet and nutrition (with standard error bars). (d) Poverty rates in different types of villages.

cate significant land-use change dynamics in Jambi driven by various socioeconomic and policy factors. Smallholder oil palm expansion occurs at the expense of rubber, bush, and forest land. The importance of contract schemes, which played a crucial role in initiating smallholder oil palm cultivation in the 1990s and early-2000s, has diminished more recently (Fig. 17a). Oil palm cultivation has positive effects on smallholder living standards (Fig. 17b), food security and nutrition (Fig. 17c). Furthermore, the expansion of oil palm has contributed to rural poverty reduction on a broader scale, including for non-farm households (Fig. 17d). Nonetheless, our findings also highlight that limited access to financial capital and other constraints have prevented many small farm households from cultivating oil palm. Our results suggest that oil palm cultivation contributes to changing gender roles within households and communities and to structural transformation with increasing farm sizes over time. Moreover, we found that farm households in Jambi pursue diversified livelihood strategies (farm and non-farm livelihood activities), even if their farming system is highly specialized.

Over the past 12 months (07/2022-06/2023), our research focused on the sustainability of smallholder oil palm production, particularly on the use of natural land management practices by farm households in their plantations. We analyzed the relationship between specific natural land management practices and oil palm yield. Additionally, we conducted a systematic review of the literature on RSPO (Roundtable on Sustainable Palm Oil), the only internationally recognized palm oil sustainability certification scheme, to understand whether or not certification has positive effects on the environment, oil palm yield, and human welfare. We also investigate and compare the contribution of oil palm production outside Southeast Asia to farm household diets and food security using data from Cameroon collected by colleagues in a different project. Related manuscripts have either been submitted or are near to submission to academic journals. Also, we are currently analyzing the data from Costa Rica to examine the determinants of farmers' replanting mechanisms for old oil palm plantations. Finally, we are contributing to the Landscape Assessment of EFForTS and Synthesis papers by analyzing the socioeconomic survey datasets we have collected to explore the relationships between land-use composition and configuration and regional economic and social development.

C08

TITLE: Designing effective policy instruments to induce sustainable land use

TEAM: Principal Investigators: Meike Wollni (UGoe); Edison (UNJA).
Scientific Staff: Tobias Bähr (Doctoral Researcher, UGoe).
Associated Scientists: Jana Juhrbandt (Research Associate, UGoe), Immanuel Manurung (Doctoral Researcher, UGoe).

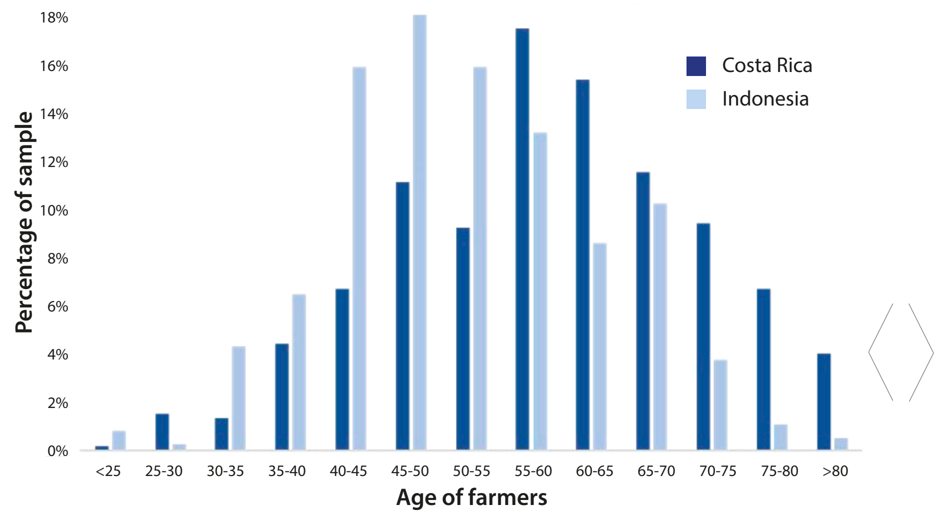
RESEARCH SUMMARY:

During Phase 3 of EFForTS, we collected data from household interviews and experiments in both Indonesia (remotely) and Costa Rica (jointly with C01 & C07).

One focus of this phase is to identify succession patterns among oil palm smallholders and understand consequences of these patterns. Both Indonesia and Costa Rica show an ageing population of smallholders with Costa Rica on the more advanced end (Fig. 18, left side). Similarly, in both countries smallholders struggle to find a successor with children moving to the cities for better job opportunities. 40% of smallholders in Indonesia and almost 60% of smallholders in Costa Rica do not have a successor (Fig. 18, right side). This has direct implications for the farmer's behavior. Having an active successor (i. e. a successor working actively on the plantation) increases the likelihood to replant in both countries! (Table 2). However, passive succession (i. e. the successor is not involved on the plantation) only has a positive effect in Indonesia. For both countries, cooperative membership increases the likelihood to replant. In a forthcoming paper, we further analyze the similarities and differences of these trends and see what insights can be drawn from comparing the two countries.

Table 2. Comparing the effect of succession on replanting behavior in Indonesia and Costa Rica

Probit Model Results		
	Dependent variable:Plan to replant in the next 5 years	
	Indonesia	Costa Rica
Active Successor	1.07***(0.33)	0.55**(0.27)
Passive Successor	0.62**(0.23)	0.10(0.26)
Cooperative Member	0.92***(0.30)	0.72***(0.23)
Constant	-4.46***(0.98)	-4.06***(0.95)
Controls	YES	YES
Observations	366	361
Log Likelihood	-86.46	-86.54
Note:	Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1	



	Costa Rica	Indonesia
ActiveSuccessor	15%	23 %
PassiveSuccessor	26%	36 %
Nosuccessor	59%	40 %

Figure 18. Age distribution and succession plans of farmers in Costa Rica and Indonesia

Sustainable Village Project:

In March 2023, Immanuel Manurung collected data on the understanding and perception of sustainability through semi structured interviews with 51 villagers. Furthermore, preferences for sustainable activities in the field of land use, value creation and social village life as well as underlying motivations were collected. In addition, focus group discussions on past and current land use and village institutions helped to develop a deeper analysis of the underlying economic, social and institutional changes in the village that lead to current unsustainable path dependencies. This lays an important foundation for the overall goal of this transformative action research approach, that focuses on catalyzing, documenting and analyzing transition management in a community arena.

C10

TITLE: **Localized environmental and land use policies, palm oil conversion and deforestation**

TEAM: Principal Investigators: Krisztina Kis-Katos (UGoe); Nunung Nuryartono (IPB University); Dearmi Artis (UNJA).
Scientific Staff: Tobias Hellmundt (Doctoral Researcher, UGoe).
Associated Scientist: Elías Cisneros (Assistant Professor, University of Texas, Dallas, USA).

RESEARCH SUMMARY:

Our project group examines socioeconomic, political, and environmental dynamics of the palm oil boom in Indonesia. We hereby integrate remotely sensed land use data with socioeconomic and policy data at the national and local level. A key focus is on the role of economic and political incentives in Indonesia's rural transformation.

Picture 17.

One research project explores the relationship between incentives for palm oil expansion and violent social conflicts linked to unequal property rights and land scarcity. We studied the impact of Indonesia's oil palm boom on local conflict using data from 2,740 rural sub-districts from 2005 to 2014, combining expansion pressure indices with detailed violent conflict event data, We find that incentives for new plantations can cause violent disputes over land and resources and lead to conflicts around local elections. Land scarcity, inequality and social grievances explain this effect. Once plantations are established, the affected sub-districts face increased risks of labor-related and inequality-driven conflict due to economic shocks such as droughts or price drops.

Another research project focuses on political incentives and their impact on deforestation in Indonesia through the district splitting process. State decentralization often aims to improve public services but its effects on forests and land use change are ambiguous. By analyzing changes in government responsibilities at new administrative borders, we studied forest outcomes within old and newly forming districts. Our findings indicate no significant changes in forest cover around future district boundaries (Fig. 19a). However, deforestation declines in the new districts compared to the existing ones after a child splits away from its

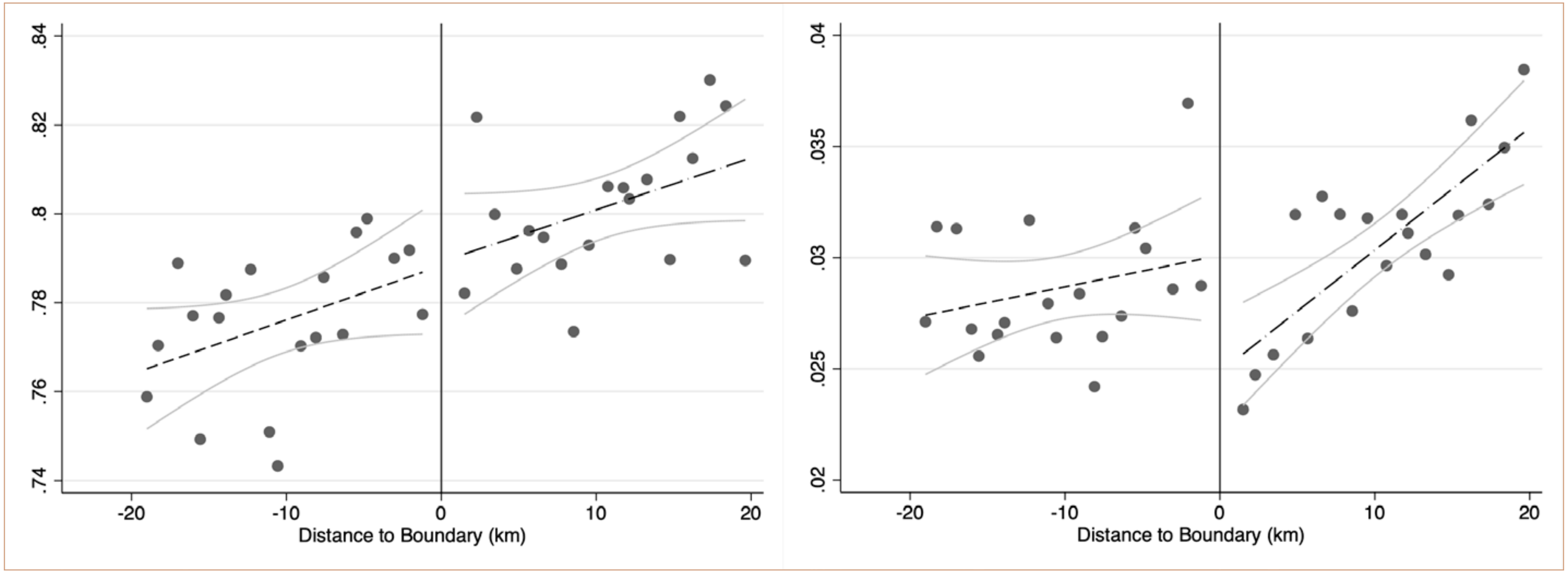


Figure 19. Spatial RDD: Initial forest cover and forest loss around new district boundaries.
Note: Dots represent binned forest cover (panel A) and forest loss (panel B) means at each side of the new district boundary for our sample of 115 district splits. The left of each side displays villages located in mother districts, whereas the right side shows villages in the newly formed child districts. Before splitting (panel A), forest cover increases continuously at the boundary as splitting is located in more remote areas. After splitting (panel B), short-term forest loss from the year of the split to three years after the split significantly declines at the border. Dashed lines are linear fits of the data with 90% confidence intervals.

mother district (Fig. 19b). In the long run no lasting local forest conservation benefits can be found.

In other studies, we examined the impact of economic incentives for intensive agriculture expansion on forest fragmentation in Southeast Asia, as well as the effects of natural disasters on deforestation in Indonesia. We are finalizing all of these studies for publication and are working on two additional projects: one investigating the link between forest-fire related haze and protests, conflicts, and local political outcomes, and another studying the relationship between oil palm prices, yield increases, and the land-use rebound effect across Indonesian districts.

C11

TITLE: **Integrated analyses of policies for sustainable rural economies**

TEAM: Principal Investigators: Jann Lay (GIGA Hamburg), Marife Corre, Ingo Grass, Kerstin Wiegand, Meike Wollni (UGoe); Nunung Nuryartono (IPB University); Aiyen Tjoa (UNTAD).
Scientific Staff: Anette Ruml (Postdoctoral Researcher, GIGA Hamburg).

RESEARCH SUMMARY:

In this project phase, we have focused on two main research activities: Firstly, we assessed the effectiveness of RSPO certifications among small-scale farmers. Secondly, we constructed a comprehensive social accounting matrix (SAM) that captures all economic activities within a stylized local rural economy (Fig. 20). This SAM serves as a valuable tool for conducting policy analyses.

For the first research activity, we relied on a comprehensive household data set that had been collected in the previous project phase by C04, in 2017 and 2018. These households are so-called scheme smallholders, which means that their production is closely linked to the mill that purchases their fresh fruit bunches (FFBs). We thoroughly analysed the data to investigate the implications of RSPO certification on the socioeconomic-ecological trade-offs of smallholder oil palm production. Our findings show that certified smallholders have higher levels of land productivity and profitability, although they also exhibit elevated rates of fertilizer and pesticide application. However, it is noteworthy that the choice of pesticides has improved, as there is evidence of a shift away from paraquat, which poses significant risks to both humans and the environment. Additionally, we have identified a subgroup of farmers who are well-informed about their certification status, and they experience considerably improved socioeconomic-ecological trade-offs.

For our second research activity, we first defined a stylized local rural economy in the study setting. This economy revolves around a central large-scale plantation and processing facility, encompassing all villages that are economically linked through the supply of agricultural labor and/or FFBs. Based on existing data and knowledge within the CRC, we were able to clearly define and calculate the economic activities in this economy. These activities include the smallholders' agricultural production (incl. oil palm, rubber and other crops and livestock), the plantation's production of oil palm and the mill's processing of palm oil. Within the villages, we also have retail, trade, service, and manufacturing sectors. The calculated SAM, which includes all these activities, can now be used to derive important economic information about such stylized economies, such as the gross domestic product (GDP), each sector's output share, and the income distribution. Currently, we are using this SAM to simulate different growth and policy scenarios, to better understand their implications on such an aggregated scale.

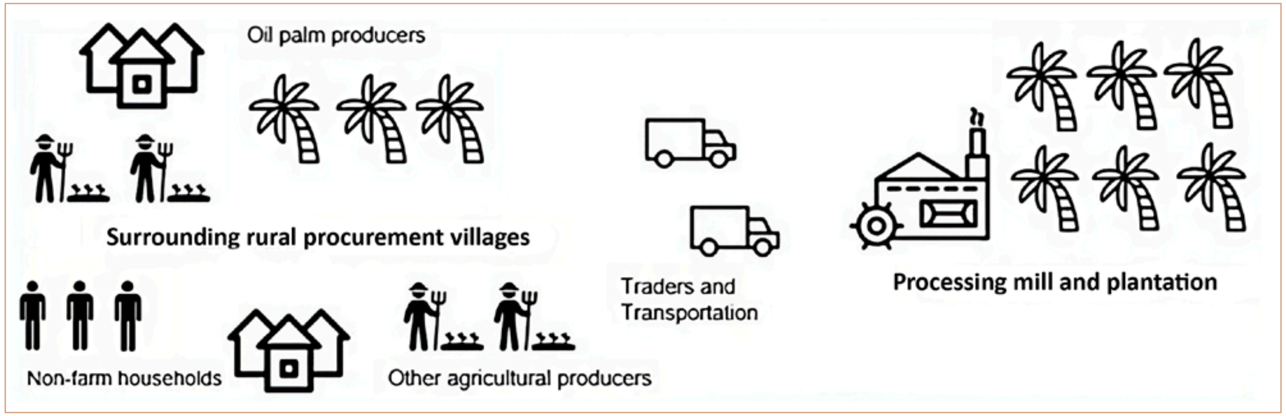


Figure 20. A stylized local rural economy.

C12

TITLE: **Collaborative farm-modelling for reconciling socio-economic and ecological functions**

TEAM: Principal Investigators: Carola Paul (UGoe); Leti Sundawati (IPB University); Bambang Irawan (UNJA).
Scientific Staff: Volker von Groß (Doctoral Researcher, UGoe).
Associated Scientist: Kai Husmann (Postdoctoral Researcher, UGoe).

Picture 18. A visit to the city of Goslar with our counterpart Leti Sundawati.

RESEARCH SUMMARY:

Our project investigates suitable farm designs, which mitigate trade-offs between ecological and socioeconomic functions. For this purpose, we published *optimLanduse*, an R package for multi-objective optimization of land-cover composition under uncertainty (Husmann *et al.*, 2022), which provides tools for easy and systematic applications of the model of Knoke *et al.* (2016). We further advanced the package with an efficient, automated search function. This extension allows for generating land-use allocations satisfying all possible combinations of ecosystem services or functions considered. With this, we identified the ecological or socioeconomic functions that yield a land-use allocation as close as possible to the current average farm portfolio. Additionally, we investigated which functions can be achieved with only minor land-use changes ("low-hanging fruits"), or which ones necessitate major changes in the land-use composition ("moonshot"). The ecological and socioeconomic functions used here were derived from the 2018 household surveys by C07, Clough *et al.* (2016), Zemp *et al.* (2019), and Grass *et al.* (2020). We used indicators, including Stand structural complexity index, Organic carbon, Labor cost, Profit, etc., to reflect the different land-use alternatives' ecological and socioeconomic functions. The land-use alternatives considered are jungle rubber, rubber plantation, and oil palm plantation. We excluded the land-cover type forest because we only added options that the farmers can currently change. The mean values and uncertainties (standard deviation) of these indicators built the data set for our approach, which consists of 3 main components. (1) A normative part that helps identify the optimized land-use composition of a hypothetical multi-functional agricultural landscape based on the land-use optimization model by Knoke *et al.* (2016) and Husmann *et al.* (2022). (2) A quasi-positive application of the optimization method for understanding the ecological and/or socioeconomic functions that influence current land-use decisions. (3) A simulation optimization of potential transformation scenarios, highlighting the transition from the current land-use distribution towards the normative "multifunctional" optimum.

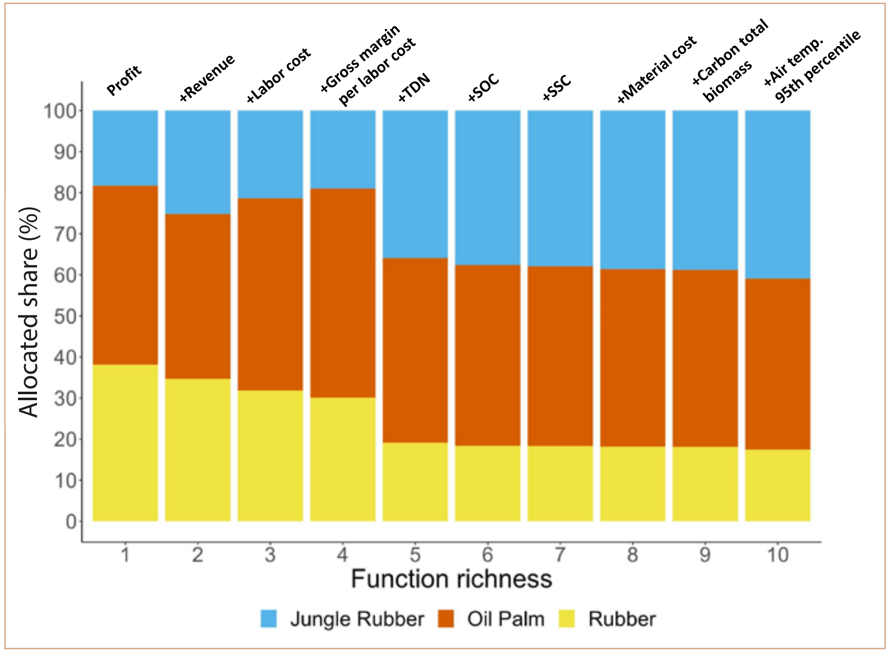


Figure 21. Transformation scenario reflecting the transition from the current land-use distribution towards the normative multifunctional optimum. Starting with the optimized portfolio that best describes the current land-use decision (function richness, i. e. number of ecological and/or socio-economic functions considered in the model) 1) and ending with a portfolio simultaneously optimizing all indicators (function richness 10). The portfolios in between are calculated after cumulative adding one more indicator reflecting functions to the previous portfolio. For example, the portfolio for function richness 5 includes the indicators Profit, Revenue, Labor cost, Gross margin per labor cost, and TDN. The indicator added is chosen based on its minimal Bray Curtis dissimilarity compared to the currently observed average farm portfolio.

Optimizing the land-use allocation for all considered indicators simultaneously resulted in a hypothetical multifunctional agricultural landscape portfolio with high shares of jungle rubber (41%) and oil palm plantation (42%) and a smaller share of rubber plantation (17%) (function richness 10 in Fig. 21). Concurrently, the research showed that the portfolio most similar to the observed land-use composition could be achieved when land-use allocation is optimized for a single indicator, Profit. This land-use composition, comprising 18% jungle rubber, 44% oil palm plantation, and 38% rubber plantation (function richness 1 in Fig. 21), is very similar to the currently observed average farm portfolio. Starting from this portfolio, we cumulatively increased the number of ecological and socioeconomic functions considered in the optimization. The socioeconomic indicators required the lowest change in land-use composition ("low-hanging fruits"), suggesting that many economic indicators show their highest levels for the same land-use type (oil palm plantations). However, including the first ecological indicator in the optimization, Total dissolved nitrogen, resulted in a significant change ("moonshot") in the land-use composition (function richness 5 in Fig. 21). The proportion of jungle rubber increased drastically, while shares of oil palm and rubber plantations were reduced. Even though the model is not designed to give exact representations of current or desirable landscapes, we could identify two main messages for agricultural smallholder landscapes in Jambi. (1) A hypothetical multifunctional agricultural landscape includes a balanced mix of intensive crops (here, oil palm and rubber) and environmental-friendly alternatives, with rubber plantations being the least chosen land-use alternatives in our case study. (2) More extensive changes are required to satisfy even one ecological indicator. This change might decrease economic performance for the farmer, suggesting the need for financial incentive measures to balance the impact.

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Husmann K, von Groß V, Bödeker K, Fuchs JM, Paul C, Knoke T (2022) optimLanduse: A package for multiobjective land-cover composition optimization under uncertainty. Methods in Ecology and Evolution *doi: doi.org/10.1111/2041-210X.14000*

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Scientific projects Z02

Z02 FIELDS OF RESEARCH
- Monitoring of meteorological variables
- Remote sensing
- Monitoring of aboveground animal biodiversity
- Function as central unit of the Convention of Biological Diversity (CBD)

INF FIELDS OF RESEARCH AND DATA MANAGEMENT
- Statistical consulting
- Data management and data long-term sustainability
- WebGIS integration and support
- Research data consultation, support and training
- Network, dissemination, outreach

Z02 – Central Scientific Service Project

TITLE: **Monitoring meteorological variables (WP1)**

TEAM: Principal Investigators: Alexander Knohl (UGoe); Dodo Gunawan (BMKG).
Scientific Staff: Christian Stiegler (Postdoctoral Researcher, UGoe).
Technical Staff: Marek Peksa, Edgar Tunsch (UGoe).

RESEARCH SUMMARY:

Within Z02, we monitored micrometeorology and studied land-atmosphere interactions in land-use transformation systems in Jambi Province by (1) performing continuous below-canopy microclimatic measurement across a total of 32 forest, rubber and oil palm locations; (2) monitoring open-land reference microclimate across a total of 6 locations in Harapan and Bukit landscape; and (3) monitoring vegetation structure and below-canopy microclimate across a total of 124 forest, shrub, smallholder oil palm and rubber plantations during the period May to December 2021, using a Rapid Ecological Assessment approach.

Land use types differ in their microclimate. Our long-term measurements in 32 plots revealed that oil palm and rubber plantation are warmer and drier compared to forests (Meijide *et al.* 2018). Our recent analysis of meteorological and airborne laser scanning (ALS) data across 124 plots showed that forests and fallow shrublands are generally cooler, wetter and receive lower below-canopy radiation compared to agricultural systems and open land. Forests show a strong capacity to buffer high levels of open-land air temperature and atmospheric vapour pressure deficit (VPD) variability by, on average, 1.7°C and 6.4 hPa, respectively, while oil palm showed very little buffering capacities (0.2°C and 2.2 hPa). Interception is an important component in the hydrology of the studied forest locations, with approx. 66% of precipitation being intercepted, while at fallow shrubland, rubber and oil palm locations, only 24, 25 and 17%, respectively, of precipitation was intercepted. A principal component analysis of ALS metrics and below-canopy microclimatic conditions (Fig. 22) showed that stand summary statistics such as leaf area index (LAI), measures of vertical structure (e. g. height, foliage height diversity), measures of complexity and heterogeneity (e. g. rumple index) and air humidity seemed to be mostly related to forest and partly to rubber locations. Below-canopy global radiation, vapour pressure deficit and metrics of vegetation gaps, were mainly related to oil palm plantations and shrub (fallow) lands. Overall, our results indicate that the high variability in meteorological conditions, even within the same land-use type, and a general shift toward warmer

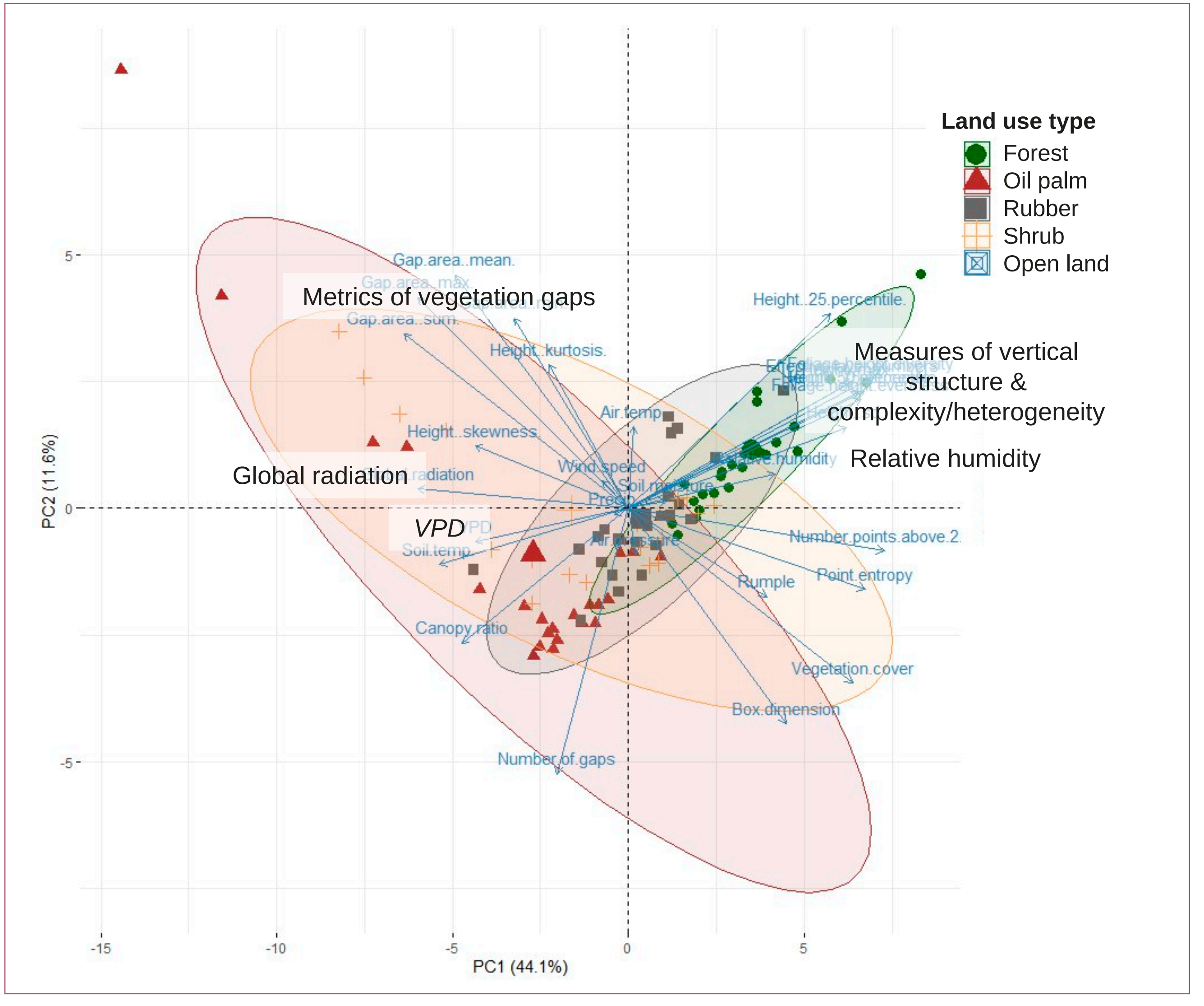


Figure 22. Principal component analysis (PCA) of airborne laser scanning (ALS) metrics and below-canopy microclimatic conditions showing clear differences in vegetation structure and microclimate between forest plots (green area) on the one hand side and oil palm (red) and shrubland plots (orange) on the other hand.

Picture 19. Measurement of below-canopy micrometeorology in PTPN6 oil palm plantation.

and drier conditions with increasing land-use intensity, may put additional pressure on ecological functions of forests and agricultural systems.

References:

Meijide A, Badu CS, Moyano F, Tiralla N, Gunawan D, Knohl A (2018) Impact of forest conversion to oil palm and rubber plantations on microclimate and the role of the 2015 ENSO event. Agricultural and Forest Meteorology 252: 208-219.doi: 10.1016/j.agrformet.2018.01.013.

Z02 – Central Scientific Service Project

TITLE: **Remote Sensing (WP2)**

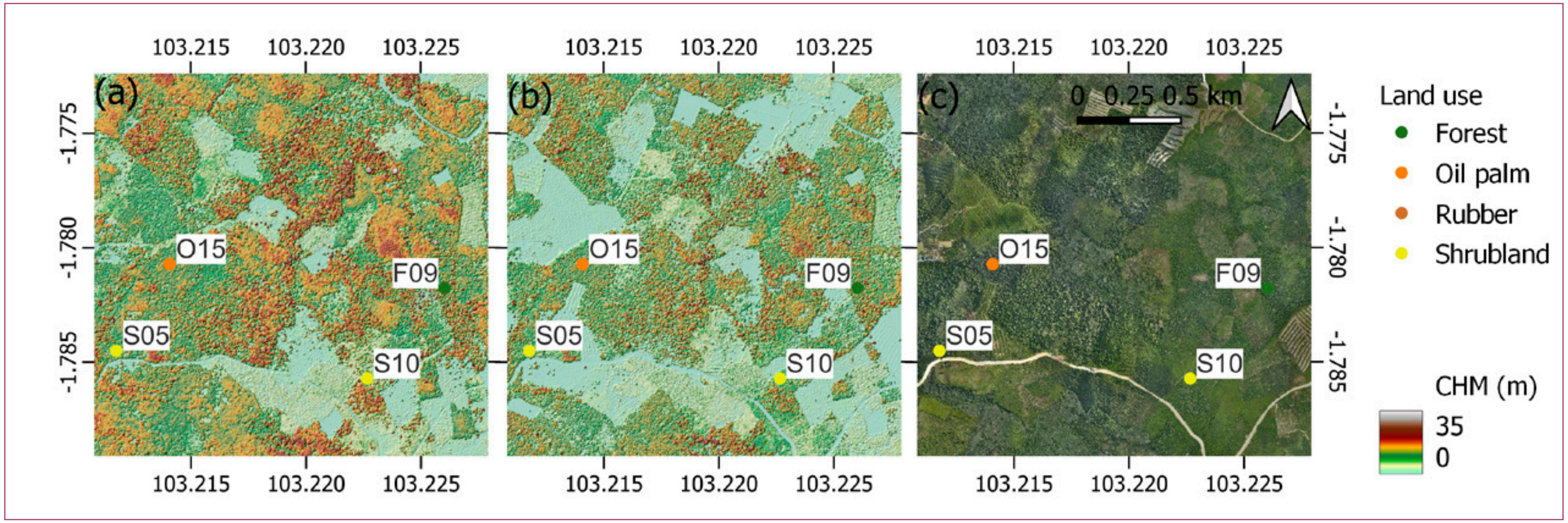
TEAM: Principal Investigators: Stefan Erasmi (Thünen Institute, Braunschweig); Nengah Surati Jaya (IPB University); Muhammad Zuhdi (UNJA).
Associated Scientist: Michael Schlund (University of Twente, The Netherlands).

RESEARCH SUMMARY:

All activities related to the parametrization of the land surface based on remote sensing are integrated in work package 2 "Remote Sensing". The main focus lies on the mapping of the 2D- and 3D-stand structure of forests, tree crops and shrubland with the support of airborne light detection and ranging (LiDAR) campaigns and hyperspectral data, and potentially upscale this information to even larger scales with the support of spaceborne data. Most of the vegetation structure mapping relies on the airborne data acquisition campaign in January and February 2020, which covered most parts of the study area and landscape assessment plots. The coverage of the study area with airborne LiDAR data was extended with an additional campaign.

The new airborne laser scanning (ALS) campaign was successfully finished in November 2022. The data was acquired with a high positional accuracy in the horizontal and vertical dimension. The general set-up, high location accuracy and high point cloud density of this campaign ensured generally the comparability with the previous data acquisition in 2020. The laser scanning data was accompanied by a simultaneous acquisition of true-color photos with a high-resolution camera resulting in a spatial resolution of 10 cm. The raw data was quality checked and processed to different products, which are generally consistent with the products from 2020. Digital surface models (DSM), digital terrain models (DTM) as well as canopy height models (CHM) were processed as basic products. A suite of various vegetation structural metrics were calculated on landscape assessment plot level as well as for the whole ALS coverage at different pixel sizes. The vegetation structural metrics include

Figure 23. (a) Canopy height model (CHM) from 2020, **(b)** canopy height model from 2022 and **(c)** RGB image from 2022 for a subset of the landscape assessment area in EFForTS (resolution: 1m LiDAR, 10 cm RGB; source: airborne LiDAR and optical campaign February 2020 and November 2022).



e. g. canopy density, number of layers, vegetation cover and height percentiles. Similar to the data from 2020, the newly acquired data is available to all sub-projects of EFForTS. The visual comparison of the canopy height models and vegetation structural metrics between the two campaigns confirmed the high dynamic of the study area, where large areas of substantial decrease (selective logging, area conversion) are revealed (Fig. 23). In addition to the vegetation structural metrics, topographic features like slope and aspect were calculated from the DTM.

In addition to the airborne data, spaceborne data from the international space station (ISS), GEDI, as well as from different satellite missions like TanDEM-X were used to map the vegetation structure beyond the airborne coverage and to provide information on larger scale. For instance, semi-empirical models were established to extrapolate the vegetation height retrieved from GEDI to the wall-to-wall coverage of TanDEM-X. Here, the airborne data substantially supported to explain the models and generally to bridge the gap between local and regional scale.

Z02 – Central Scientific Service Project

TITLE: **Monitoring aboveground biodiversity: Canopy Arthropods (WP3)**

TEAM: Principle Investigators: Stefan Scheu (UGoe); Damayanti Buchori, Purnama Hidayat (IPB University).

Scientific Staff: Jochen Drescher (Postdoctoral Researcher, UGoe).

Associated Scientists: Melanie Maraun (Postdoctoral Researcher, UGoe), Tamara Hartke (Scientist, ZFMK Bonn), Danilo Harms (Scientist, CeNAK Hamburg), Martin Husemann (Scientist, NKM Karlsruhe); Azru Azhar, M. Naufal Rizqulloh (Doctoral Researchers, UGoe).

Local Assistants: Desi Anggrahini, Rizky Desriana, Indah, Naufal Urfi Dhiya'ulhaq, Ferdian, Kasmiatun, Rizky Nazarreta, Rani Novita, Anik Nurhayati, Lia Nurulalia, Bona Pakpahan, Ulfa Ulinnuha

RESEARCH SUMMARY:

From 2022-2023, we focused on completing three aims set for Phase 3 of EFForTS: (1) Publish general biodiversity patterns, and field guides, of focus taxa collected in Phase 1; (2) create new data from arthropod collections in EFForTS core plots from Phases 1 and 2; (3) continue work on arthropod collections from EFForTS Phase 3, i. e. the Landscape Assessment and Biodiversity Enrichment Experiment.

OBJECTIVE 1:

Since July 2022, or the last EFForTS Newsletter issue, we were able to publish three papers on biodiversity and population declines of canopy arthropods. Overall, we observed a striking similarity of newly reported patterns in spiders beetles (Kasmiatun *et al.*, 2022), spiders (Ramos *et al.*, 2022) and collembola (springtails, Mawan *et al.*, 2022) to those in arthropods previously reported on, i. e. ants, parasitoid wasps and butterflies: EFForTS rubber and oil palm sites contained half the species and the population density as core plots in rainforest, at most.

Biodiversity and population declines differed between taxa, however. In a collection of ca. 50,000 beetle specimens, the abundance and biomass of three beetle families (Chrysomelidae, Elateridae, Staphylinidae) declined along the land-use gradient as expected, but average abundance and biomass of weevils (Curculionidae) in oil palm was as high as in rainforest sites (Kasmiatun *et al.*, 2022). This pattern was due to the introduced oil palm pollinator *Elaeidobius kamerunicus*, which dominated Curculionid abundance and biomass in oil palm. Beetle richness, however, declined along the land-use gradient by more than 50% for all beetle families. The findings of this paper were further supported by the "Guidebook of Beetles and Weevils of Jambi, Sumatra, Indonesia (Chrysomelidae, Curculionidae, Elateridae and Staphylinidae)" (Hidayat *et al.*, 2022), complete with images of more than 500 beetle species

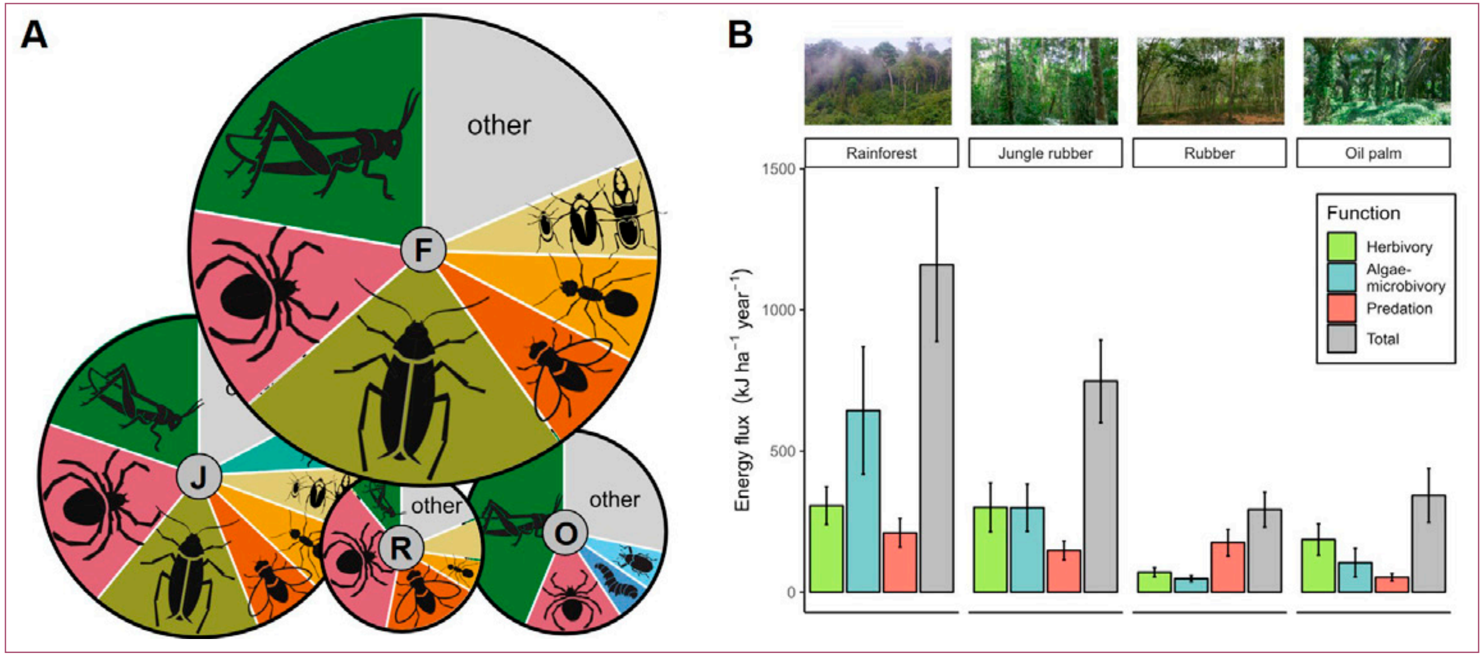


Figure 24. (A) Relative canopy arthropod biomass declines from rainforest (F) vir jungle rubber (J) to rubber and oil palm (O) plantations; size of circles represents biomass, and pies represent contributions of individual taxa. **(B)** Energy flux declines and functional change of the canopy arthropod food web, both overall (grey) as well as for three trophic functions.

and dichotomous identification keys to the subfamilies and genera of those four beetle families.

We also explored the role of biotic and abiotic environmental factors such as tree richness or temperature on the community composition of a collection of more than 10,000 arboreal spiders from >400 morphospecies. Canopy openness, tree biomass and density, and vascular plant richness were the factors significantly influencing the taxonomic and density-dependent contrasts between spider communities from rainforest, jungle rubber, rubber and oil palm (Ramos *et al.*, 2022).

In collembolans, the environmental factors influencing community composition even differed between seasons: In a collection of almost 80,000 springtail individuals from 68 species, structural complexity (SSCI) consistently influenced collembolan community composition in both dry season 2013 samples and rainy season 2013/2014 samples. Litterfall and tree biomass were only relevant in dry season samples, and ambient temperature only for collembola and from the rainy season (Mawan *et al.*, 2022).

As a highlight of the past year, we were also able to publish a highly anticipated study of ours that was years in the making. In it, we quantify energy flux declines in the canopy arthropod food web along the land-use gradient in EFForTS and show how this land-use change is associated with a fundamental shift in functional ecology of the canopy arthropod food web (Pollierer, Drescher *et al.*, 2023). Specifically, biomasses of canopy arthropods declined by up to 80% after rainforest conversion to rubber or oil palm (Fig. 24A), and energy fluxes by up to 75% (Fig. 24B). At the same time, trophic strategies shifted from predominantly algae-microvory in rainforest to predation in rubber and herbivory in oil palm (Fig. 24B). Our study highlights that the ongoing loss of animal biodiversity and biomass in tropical canopies degrades animal-driven functions and restructures arthropod-driven food webs in cash crop canopies.

Picture 20. The Z02 WP3 team at the Animal Ecology Department, University of Göttingen (From left to right: Naufal Urfi Dhiya'ulhaq, Ulfa Ulinnuha, Rani Novita, Lia Nurulalia, Ferdian, Kasmiatun, Tamara Hartke, Naufal Rizqulloh, Azru Azhar, Jochen Drescher).

Picture 21. The Z02 WP3 team at the Plant Protection Department, IPB University (from left to right: Rizky Nazarreta, Bona Pakpahan, Desi Anggrahini, Indah, Damayanti Buchori, Purnama Hidayat, Anik Nurhayati, Rizky Desriana, Lidia Sari).

OBJECTIVES 2+3:

We are currently in the writing phase of several manuscripts originating from BSc and MSc theses at the Animal Ecology group at Göttingen University. Those include studies on land-use change effects on (a) *Crematogaster* ant community trophic structure (Jessica Ehlers, B.Sc.), (b) the taxonomic and functional decline of ants from canopy, litter and soil (Noah Janotta, B.Sc. follow-up), (c) functional decline and trophic changes of beetles (Coleoptera, Valentine Laurent, M.Sc. thesis), and (d) a community phylogenetic study on Chrysomelidae, detailing how rainforest transformation to oil palm may lead to the extinction of an entire subfamily of leaf beetles (Radit Sawaskorn, M.Sc. thesis). We are also continuously preparing new data on flies (Diptera), true bugs (Hemiptera), caterpillars (Lepidoptera) and spiders (Araneae) from the 2013 collection in the framework of ABS-funded research visits by Indonesian students from IPB University to the Animal Ecology Department in Göttingen (Pic. 20). We are also revising our spider collection from EFForTS core plots 2013, as well as identifying ants from the EFForTS Landscape Assessment in the framework of an ABS funded research visit (Pic. 20, details see ABS reports). At the same time, further sorting and data analysis from EFForTS core plot collections in 2017, EFForTS Landscape Assessment, and EFForTS Biodiversity Enrichment Experiment are ongoing in the Department of Plant Protection, and the Taxonomy Unit, at IPB University, with a mix of students in their B.Sc. and M.Sc. theses, and local research assistants (Pic. 21).

Public relations – Project Ö (PR)

TITLE: **Teacher education for society: Making *EFForTS* knowledge available for Indonesia**

TEAM: Principal Investigators: Susanne Bögeholz (UGoe); Leti Sundawati (IPB University); Upik Yelianti (UNJA); I Nengah Suparta (Undiksha, Bali).
Scientific Staff: Finn Matthiesen (Junior Scientist, UGoe).
Associated Scientist: Sabina Eggert (Central Institute for Teacher Education and Research, UGoe).

RESEARCH SUMMARY:

From May 2021 until June 2023, almost 1.000 students from higher education in Indonesia (477 science teacher students, 498 students of forestry study programs) and 17 Indonesian lecturers participated in EFForTS education modules. The teaching and learning focused on making knowledge on EFForTS BEE and EFForTS OPMX available. EFForTS education took place in nine different courses at four higher education institutions (IPB University Bogor, UNJA, Undiksha, State University of Malang). Each course lasted about five weeks.

Currently, we develop an open book that compiles EFForTS educational resources, concepts, and evaluations reports (*https://opmx-preview.web.app/*).

Research showa throughout positive effects of the educational modules. The positive effects are with respect to instructional design, self-rated knowledge on and individual interest in *oil palm management, crop cultivation, scientific research*, and *sustainable development* (topic dimensions). Furthermore, there is evidence for the utility value (usefulness) of the educational modules concerning these topics.

Next, we illustrate the positive effects of EFForTS education in an example. Thereby, we use students' utility value development in the different topic dimensions. Utility value can be understood as the perceived usefulness of learning about a topic.

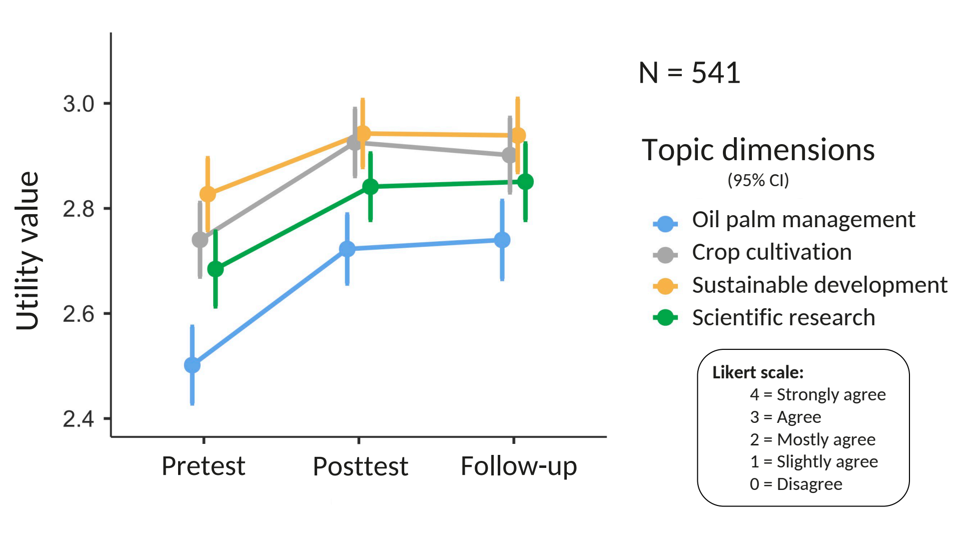


Figure 25. Students' perceived utility value of topic dimensions before (pretest), after five-weeks working with the educational modules (posttest), and two months later (follow-up).

Overall, the perceived utility value of the students is increased at the end of the educational modules (posttest) and does not decrease two months later (follow-up). However, there are differences in the perceived utility value of topic dimensions (Fig. 25). Students rate the usefulness of learning about the general dimensions *crop cultivation, sustainable development, and scientific research higher than the specific dimension oil palm management.*

From a science education perspective, the differentiated analysis of utility value topic dimensions is innovative. It can be used to evaluate and improve educational modules. Moreover, such analysis is useful to promote and assess learners' motivation to sustainable development issues.

Picture 22. Team members of EFForTS education.

From a science communication perspective, the investigated students' perceived utility value of the educational modules is a strong indicator for a successful PR project. As utility value can positively influence learning outcomes, e. g., knowledge, interest development and career choices, EFForTS education makes EFForTS knowledge available for society now and in the future.

INF

TITLE: **Research Data Management and Integrative Statistical Analysis**

TEAM: Principal Investigators: Wolfram Horstmann (SUB, Goe), Thomas Kneib (UGoe), Ramin Yahyapour (GWDG, UGoe), Junaidi Sutan (UNTAD), Suria Tarigan (IPB, University).
Scientific Staff: Philipp Wieder, Aytaj Badirova, Faraz Fatemi Moghaddam (GWDG, UGoe), Isa Marques (UGoe), Daniel Kurzawe (SUB, UGoe).

RESEARCH SUMMARY:

Research Data Management Project

INF is responsible for the data management of the CRC 990 including operating the respective services and consulting researchers on how to make best use of them.

As reported in the previous newsletter, INF developed a sustainable research data management solution based on the GRO.data repository operated by the Göttingen Campus. This solution (Fig. 26), which offers FAIR data sets from the CRC 990 also beyond the lifetime of the project, is, after the already reported migration of the already produced data, continuously used for new data records leading to a single, comprehensive view on the project's research data. The system is well received by the projects of the CRC 990 and Through this, the research data, comprising as of today 1,124 data sets and 4,675 files, will not only be conserved, but is also citable and can be reused by scientists to answer future research questions.

Further resources have been invested into supporting sub-project A01 to update its pollen database. As the database became technically outdated during the lifetime of the CRC 990, it became essential to analyse potential solutions to upgrade or re-implement the pollen database. Following a thorough assessment of the status quo, it was initially decided to implement the database completely from scratch. Discussing the initial design, it was then decided to re-assess the situation in particular with respect to already existing databases in relevant domains. This led to an in-depth analysis of Ecotaxonomy database (*http://ecotaxonomy.org/*) as a potential destination for the data sets currently stored in the pollen DB. Finally, the decision was then made to migrate the data sets into the Ecotaxonomy database instead of pursuing an individual, new development. INF started communication and planning with the maintainers and developers of the Ecotaxonomy database. The finalisation of the process is planned during the final months of the CRC 990.

Apart from the work related to the research data repository, the INF data management group conducted several other tasks and supported researchers including: managing and supporting the general and financial document platforms (based on Microsoft SharePoint), regular consultations with EFForTS researchers from other sub-projects, as well as helping to design and develop specific information systems for some of sub-projects.

Statistical consultancy

INF provides statistical consultancy to the researchers of the CRC 990. This involves the organization of statistical workshops and theoretical and practical support regarding the analysis of research data and research collaborations.

Regarding the statistical training and workshops, three half-day workshops were organized on Zoom for the Indonesian counterparts. The first "Regression Models" workshop took place on April 28, 2023, and consisted of a theoretical introduction to regression models. On May 12, we discussed "Regression models in R," where we utilized the concepts learned in April and learned how to implement these in the software R. Finally, on June 22, we discussed "Principal Component Analysis" from a theoretical and practical perspective. The courses had an average of 20 participants and were specially designed according to the requests made by the participants. All materials, including class recordings and slides, were posteriorly shared with the participants.

The statistical consultant met with several Ph.D. and Postdocs, and sometimes master students, from the CRC to discuss diverse statistical problems. Topics ranged from regression modelling to experiment design. Some of the discussions have led to collaborative work within the CRC. Namely, with Medha Bulusu from sub-project A02 on how UAV-based thermography reveals spatial and temporal variability of evapotranspiration from tropical rainforest, resulting in a manuscript published in Frontiers In Forests And Global Change (see Bulusu *et al.*, 2023). The consultancy also collaborated with Pallavi from sub-project A02 on the Land-use change drivers of below-canopy surface temperature to be submitted. Finally, the statistics group also contributed with a speaker, Dr. Paul May (University of Maryland), to the Efforts' "LA upscaling" workshop on February 14, 2023, titled "Introduction to Data Integration". Future ideas for further collaborative work following this course could have involved the development of a workshop on upscaling the CRC's data together with Dr. Arne Wenzel.

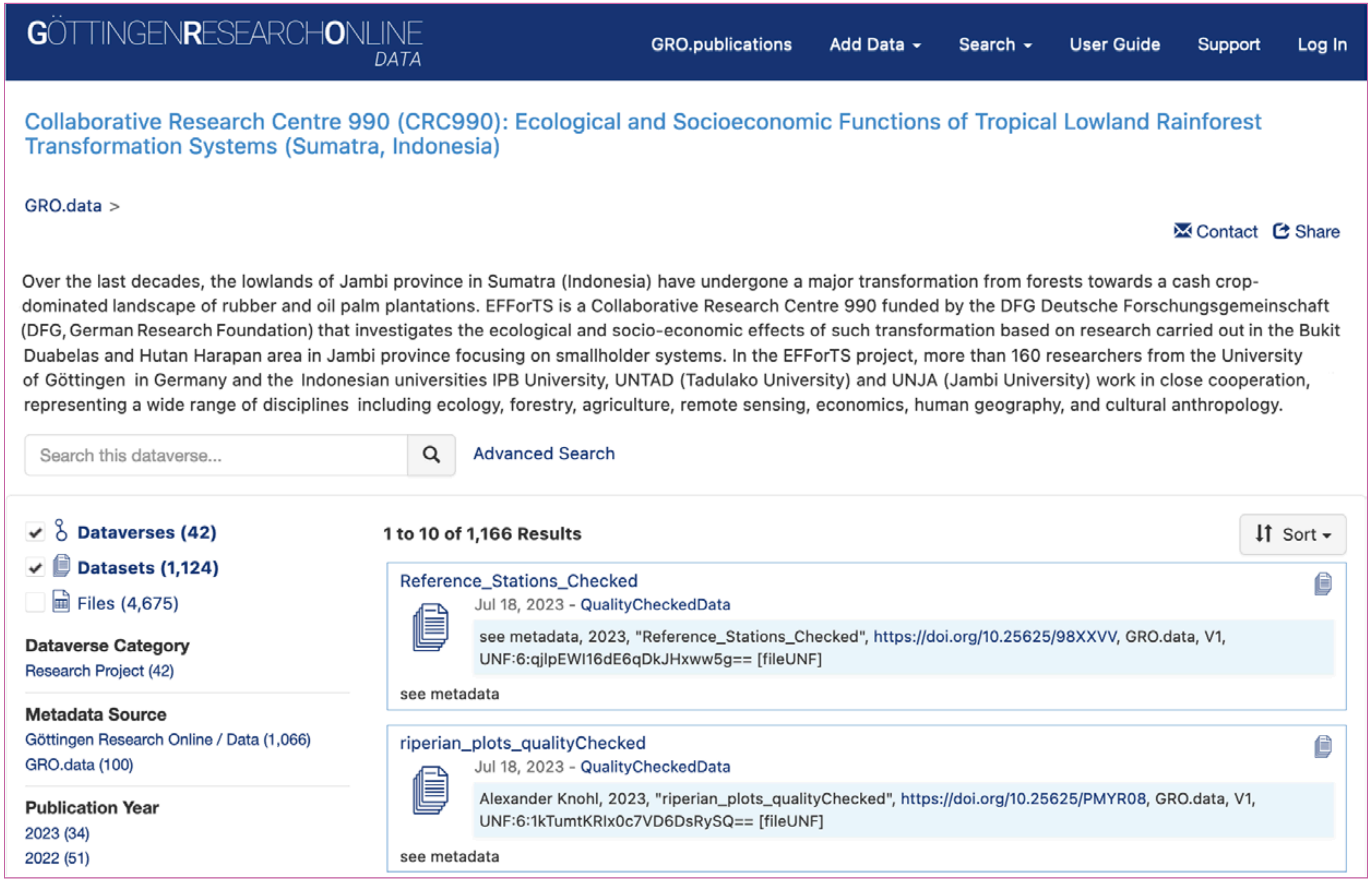


Figure 26. CRC 990 Research Data Repository showing newest published data records.

References:

Bulusu M, Ellsäßer F, Stiegler C, Ahongshangbam J, Marques I, Hendrayanto H, Röll A, Hölscher D. (2023) UAV-based thermography reveals spatial and temporal variability of evapotranspiration from a tropical rainforest. Frontiers in Forests and Global Change.;6:1232410.

II. Integration of Ecological and Socio-economic Research

Integration / integrative research activities across disciplines is realized through

- the establishment of a joint enrichment planting experiment (*EFForTS-BEE*, B11)
- oil palm management experiment (*EFForTS-OPMX*, A05)
- *Landscape Assesment* (*EFForTS-LA*, B09)
- four thematic foci / overarching joint hypotheses.

1. Integrative research activities

The enrichment experiment (*EFForTS-BEE*, B11)

TITLE: **Biodiversity enrichment in oil palm plantations: plant succession and integration**

TEAM: Principal Investigators: Dirk Hölscher, Holger Kreft, Meike Wollni (UGoe); Leti Sundawati (IPB University); Bambang Irawan (UNJA).
Scientific Staff: Gustavo Brant Paterno (Postdoctoral Researcher, UGoe).
Associated Scientist: Delphine Clara Zemp (Assistant Professor, University of Neuchâtel, Switzerland), Yevgeniya Korol (Doctoral Researcher, UGoe), Vannesa Montoya-Sánchez (Doctoral Researcher, University of Neuchâtel, Switzerland).

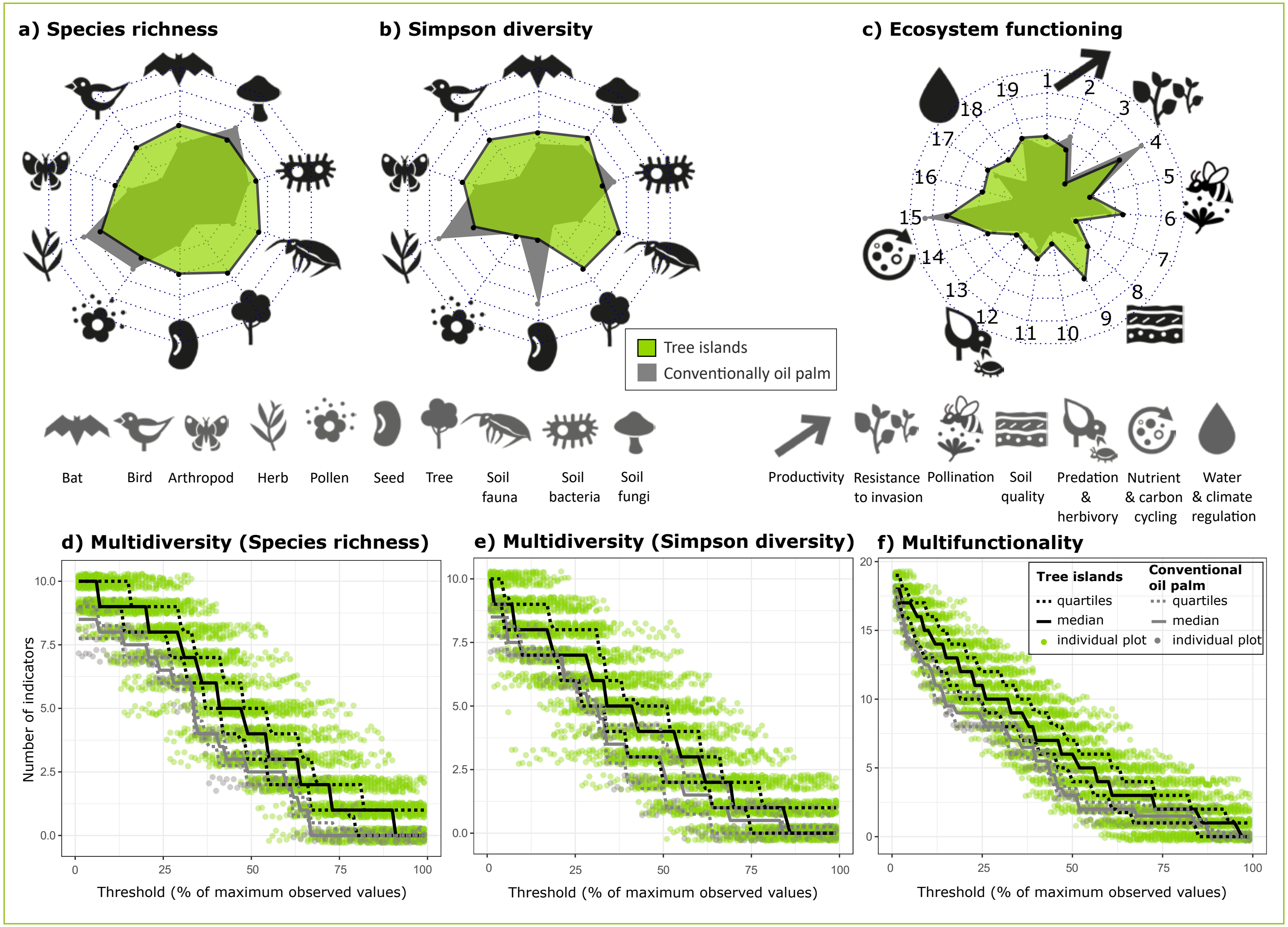
RESEARCH SUMMARY:

The conversion of tropical rainforests to oil palm monocultures has caused significant biodiversity loss and ecological degradation. This trend is expected to continue in Southeast Asia and other lowland regions, given the increasing global demand for oil. Therefore, urgent action is needed to implement sustainable management practices to alleviate the environmental effects of industrial-scale palm plantations. In the Biodiversity Enrichment Experiment EFForTS-BEE (Picture 23), we ask if enriching oil palm plantations with native trees promotes biodiversity and ecosystem functioning and how this affects oil palm yield. For ten years (2013-2023), we have monitored multiple dimensions of biodiversity, ecosystem structural complexity and functioning, and the productivity (i. e., oil palm yield) of enchained plantations (i. e., tree islands) in comparison to conventional oil palm plantations.

Picture 23. The edge between a 40 x 40 m tree island (Plot 45) on the left, and a conventional palm plantation, on the right, in the EFForST-BEE experiment, Jambi, Sumatra, Indonesia. (Picture: Gustavo Paterno, 2023).

Planted tree diversity and island area had a positive impact on the taxonomic, phylogenetic, and functional diversity of regenerating woody species. While conventional oil palm plantations have no tree regeneration under the palm canopy, large tree islands

Figure 27. Multidimensional ecological restoration outcomes in an oil palm-dominated landscape. We measured ten and 19 indicators of biodiversity and ecosystem functioning, respectively, in tree islands and compared their responses to those in plots representing conventionally managed oil palm monocultures. For ecosystem functioning, we measured: Productivity: 1- oil palm yield, 2-aboveground biomass; Resistance to invasion: 3- native seeds, 4: resistance to invasive plants; Pollination: 5- pollinators, 6- pollination rate; Soil quality: 7- soil P, 8- soil decompaction, 9- 1/soil C:N, Predation and herbivory: 10- predators (vertebrates), 11- predators (arthropods), 12- predators (soil fauna), 13- herbivores (soil fauna); Carbon and nutrient cycling: 14- decomposers, 15- litter decomposition, 16- litter input; Water and climate regulation: 17- evapotranspiration, 18- water infiltration, 19- microclimate buffering. Oil palm yield (calculated per island) is considered an ecosystem functioning due to its contribution to primary productivity, as well as agricultural productivity. Indicators of biodiversity calculated (a) as species richness and (b) Simpson diversity, which emphasizes the contribution of abundant species and (c) ecosystem functioning across 52 tree islands (green polygons) compared to oil palm monocultures (grey polygons). Polygon vertices represent median values for each indicator. Multidiversity and multifunctionality represent the number of indicators (d- species richness; e- Simpson diversity, f- ecosystem functioning) that exceed a specified threshold, which is expressed as a percentage of the maximum observed values in the oil-dominated landscape (i. e., calculated based on both island and control plots combined). (Zemp *et al.* in 2023, *https://www.nature.com/articles/s41586-023-06086-5*).



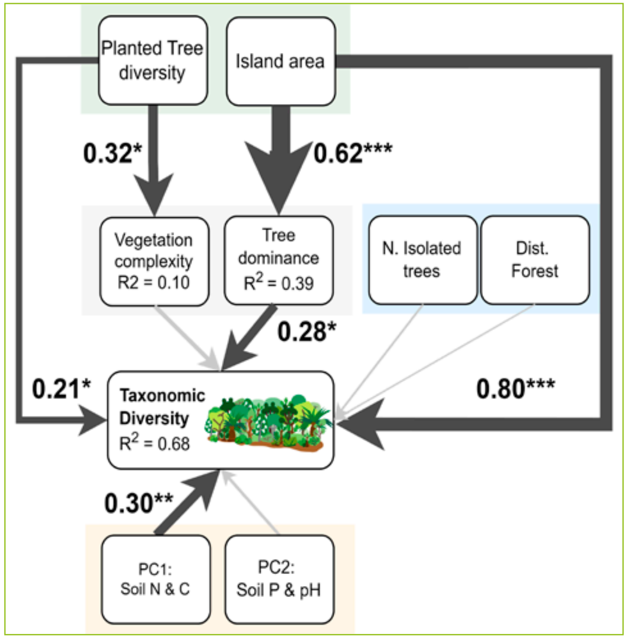


Figure 28. Results from Piecewise Structural Equation Models explaining the main drivers of observed (a,b,c) and standardized (e, f, g) diversity of the regenerating plant community for q-order 1 in EFForTS-BEE, Sumatra, Indonesia. Black arrows indicate positive effects. Gray arrows are non-significant paths (p.value < 0.05). The thickness of paths reflects standardized model coefficients (in bold). * p<0.05 ** p<0.01 *** p<0.001. Paterno *et al*. in preparation.

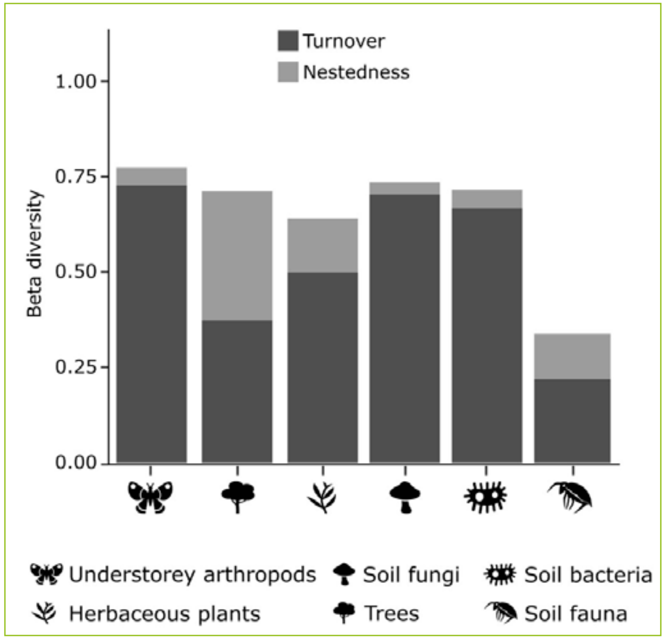


Figure 29. Beta diversity, turnover, and nestedness across tree islands of EFForTS-BEE (Jaccard index). (Montoya-Sánchez *et al.* 2023, *https://www.nature.com/articles/s43247-023-00875-6)*.

with mixed species showed the highest taxonomic, phylogenetic, and functional diversity of regenerating woody species. A piecewise structural equation model revealed that the diversity of regenerating woody species is shaped by a combination of direct and indirect effects of the experimental variables (tree diversity and island area), the vegetation structure (i. e. tree dominance in the canopy), and local soil properties (Soil C, Soil N, and low bulk density) (Fig. 28). In contrast, landscape variables (i. e. isolated trees and distance to the forest) had minor or negligible effects on the diversity of regenerating species. Establishing large and diverse tree islands within mono-specific oil palm plantations enhances multifaceted plant diversity through natural regeneration (Fig. 27). A synergistic approach combining tree planting with natural regeneration can be a cost-effective strategy to catalyze the recovery of taxonomic, phylogenetic, and functional diversity in industrial palm plantations.

Zemp *et al.* (2023) demonstrate that enriching industrial palm plantations with tree islands can significantly enhance biodiversity and ecosystem functionality without compromising agricultural productivity, as indicated by yield (Fig. 27). This finding challenges the common assumption that promoting biodiversity and ecosystem functioning is at the expense of crop production. Establishing tree islands in cash crop-dominated landscapes emerges as a viable and sustainable approach for nature and people. Additionally, our research highlights that larger tree islands result in greater gains in biodiversity and ecosystem functioning, primarily through modifications in vegetation structure. Therefore, the design and implementation of restoration strategies focused on biodiversity, and ecosystem functioning should consider the size of the tree islands.

In another synthesis study, we investigated the impact of establishing tree islands on landscape-scale diversity, specifically focusing on beta diversity across six taxa (Montoya-Sánchez *et al.* 2023). The results demonstrated that the tree islands effectively enhanced diversity by promoting the presence of unique species (as seen in turnover; Fig. 29). Our analysis of partial correlation networks revealed that variations in vegetation structure complexity and soil conditions significantly influenced multi-taxa beta diversity and turnover. To effectively enhance multi-taxa diversity, strategies should prioritize landscape heterogeneity and consider the crucial role of soil biota.

In conclusion, the studies conducted by the EFForTS-BEE team have provided compelling evidence regarding the effectiveness of tree islands in restoring biodiversity and ecosystem function in oil palm-dominated landscapes. These results will support evidence-based solutions to implement sustainable management practices in oil palm-dominated landscapes.

EFForTS-OPMX, A05

TITLE: **Reduced fertilization and mechanical weeding enhances ecosystem multifunctionality and profit in industrial oil palm plantations**

TEAM: Principal investigators: Marife D. Corre, Edzo Veldkamp (UGoe); Aiyen Tjoa (UNTAD); Bambang Irawan, Muhammad Damris (UNJA).
Scientific Coordination: Najeeb Al-Amin Iddris (Postdoctoral Researcher, UGoe).

RESEARCH SUMMARY:

Oil palm trees are the most productive oil crop and global demand is increasing. However, their productivity is associated with conventional management practices including high fertilizer usage and herbicide application, resulting in severe environmental problems such as biodiversity loss, nutrient leaching and greenhouse gas emissions. But can less intensive management of large-scale oil palm plantations enhance ecosystem functions and biodiversity without sacrificing yield and profit? To answer this question, we established the Oil Palm Management Experiment (EFForTS-OPMX) in November 2016 in a large-scale oil palm estate (PT Perkebunan Nustanrat VI) during Phase 2 of the CRC-EFForTS. The overall goal of the EFForTS-OPMX is to experimentally test whether a reduced management intensity can contribute to a more sustainable oil palm production than current conventional management. Using a full factorial field experiment of two fertilization levels × two weeding practices, we assessed the effects of conventional vs. reduced (i. e., only compensating for nutrients exported via harvests of

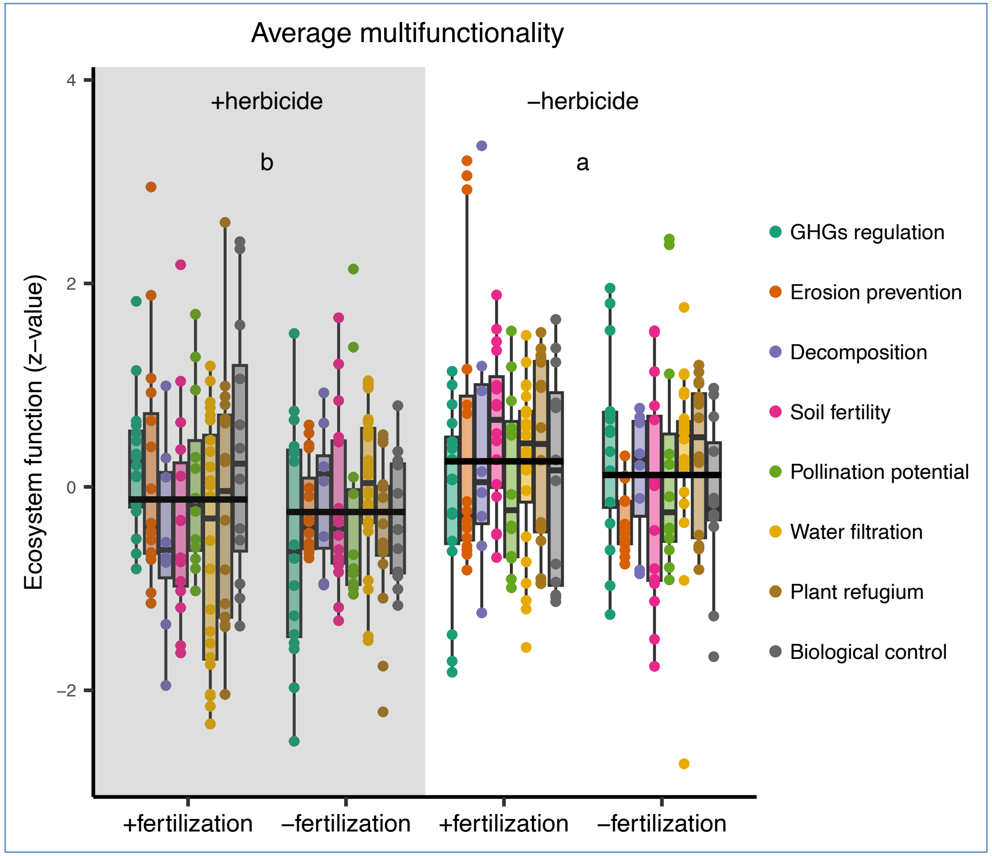


Figure 30. Box plots (25th percentile, median and 75th percentile) and whiskers (1.5 × interquartile range) are based on the z-standardized values ((actual value – mean value across replicate plots) / standard deviation) of indicators for a specified ecosystem function. $N = 4$ plots. The black horizontal lines indicate the mean multifunctionality of eight ecosystem functions. 22 factorial treatments: + indicates conventional fertilization and herbicide treatment; – denotes reduced fertilization and mechanical weeding. Different letters denote that ecosystem multifunctionality was higher in mechanical weeding than herbicide treatment (linear mixed-effects model at $P = 0.03$)

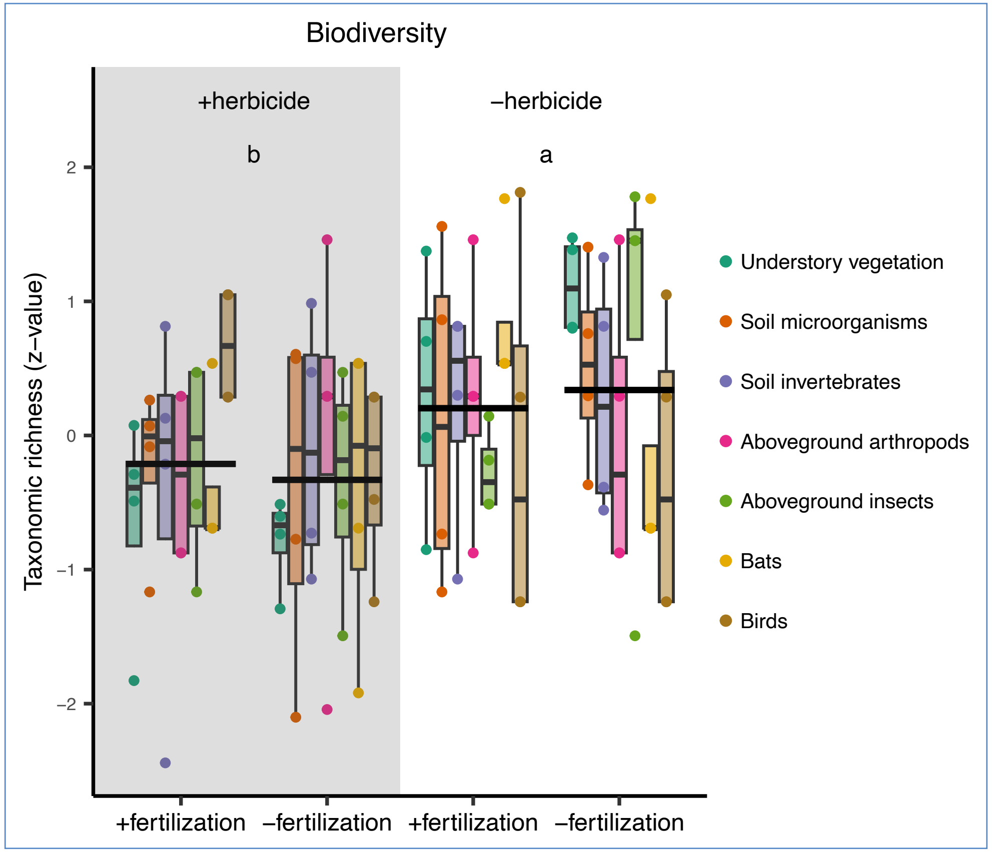


Figure 31. Box plots (25th percentile, median and 75th percentile) and whiskers (1.5 × interquartile range) are based on the z-standardized values ((actual value – mean value across replicate plots) / standard deviation) of indicators for a specified trophic group. $N = 4$ plots. The black horizontal lines indicate the mean biodiversity richness of seven multitrophic groups. 22 factorial treatments: + indicates conventional fertilization and herbicide treatment; – denotes reduced fertilization and mechanical weeding. Different letters denote that biodiversity richness was higher in mechanical weeding than herbicide treatment (linear mixed-effects model at $P = 0.01$).

oil palm fruits) fertilization rates and herbicide vs. mechanical weeding on ecosystem functions, biodiversity and profitability. Treatments were randomly assigned on 50 m × 50 m plots replicated in four blocks, totalling 16 plots. In collaboration with several subprojects, we collected data on 23 indicators of eight ecosystem functions, seven indicators of biodiversity and six economic indicators linked to the level and stability of yield and profit, during the first four years of the management experiment (Figs. 30, 31 & 32). A current synthesis of the EFForTS-OPMX results is published in the journal Nature Sustainability (Iddris, Formaglio *et al.* 2023). After four years of this experiment, mechanical weeding exhibited higher ecosystem multifunctionality than herbicide treatment (Fig. 30). This is because mechanical weeding promotes fast recovery of ground vegetation and increases its species diversity, which may enhance recycling of nutrients via root uptake, and in combination with reduced fertilizer-usage decreases leaching and increases nutrient retention in the soil. Biodiversity was also higher in the mechanical weeding than herbicide treatment (Fig. 31). This effect was mainly driven by the strong increase in ground vegetation species richness in the mechanical weeding, which also had small positive effect on other trophic groups (soil microorganisms, soil invertebrates and aboveground insects; Fig. 31). The four-year cumulative yield did not differ among treatments, but reduced fertilization and mechanical weeding increased profit by 12% and relative gross margin by 11% due to reductions in material costs (Fig. 32). Overall, the results of the EFForTS-OPMX provide strong experimental evidence that mechanical weeding, together with reduced, compensatory fertilization rates in mature, industrial oil palm plantations is a tenable management option for enhancing ecosystem multifunctionality and biodiversity and increasing profit, providing win–win situations. These management practices can be easily adopted in the field by plantation owners and workers, and can contribute to sustainability guidelines of certification bodies such as Roundtable of Sustainable Oil Palm.

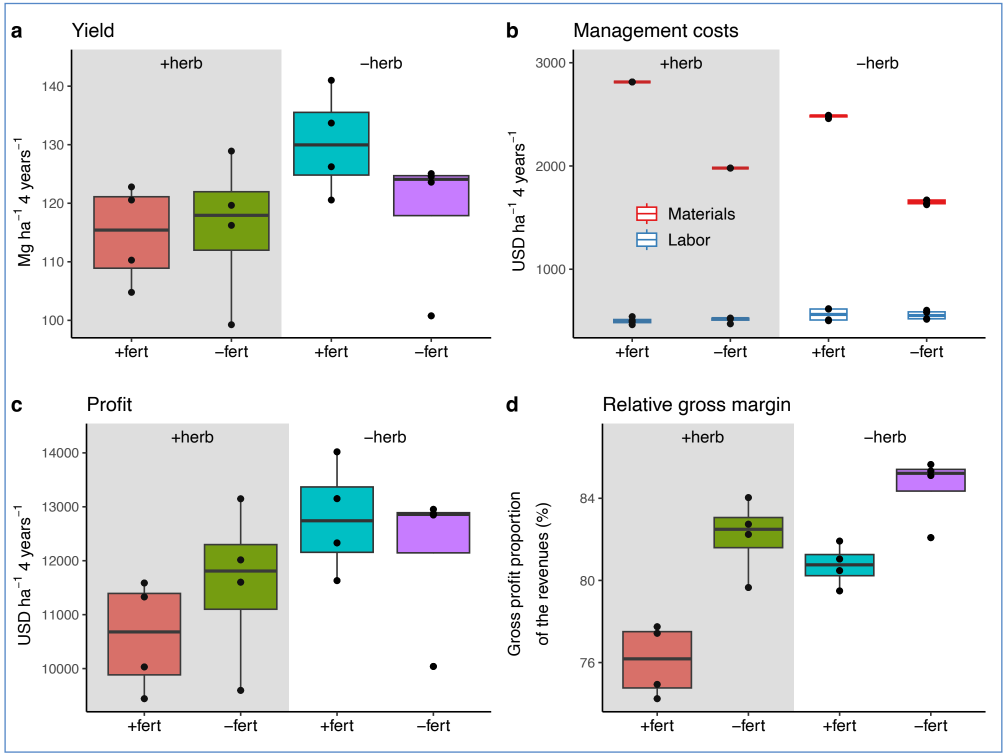


Figure 32. Oil palm yield (a), costs (b), profit (c) and relative gross margin (d) (cumulative values for 2017–2020) in different fertilization and weeding treatments ($N=4$ plots) in an industrial oil palm plantation in Jambi, Indonesia. Box plots indicate the 25th percentile, median and 75th percentile, and whiskers are 1.5 × the interquartile range. 22 factorial treatments: + Fert, + Herb are conventional fertilization with herbicide treatment; – Fert, + Herb are reduced fertilization with herbicide treatment; + Fert, – Herb are conventional fertilization with mechanical weeding; – Fert, – Herb are reduced fertilization with mechanical weeding.

Landscape Assessment (*EFForTS-LA*, B09)

TEAM: Scientific Supervisors: Catrin Westphal (B09), Ingo Grass (B09, C11), Stefan Scheu (B08, Z01, Z02).
Scientific Coordination: Arne Wenzel (Postdoctoral Researcher, B09).

RESEARCH SUMMARY:

The Landscape Assessment (EFForTS-LA) represents the latest field work platform established in Phase 3 of EFForTS. Coordinated by B09, the LA has the primary objective of going beyond the local plot scale by integrating data from previous phases into a comprehensive spatial framework. This framework encompasses 124 new field sites, strategically selected to cover various gradients, including management intensity, landscape heterogeneity, and neighboring forest cover.

The field campaign, which started in May 2021 and lasted for six months (with some sampling activities continuing until the end of 2022), involved 12 subprojects from EFForTS. The collected ecological data provides a detailed assessment of above- and belowground biodiversity and ecosystem processes, covering eleven taxonomic groups, nine ecosystem functions/processes, and ten environmental variable groupings.

Additionally, a socioeconomic household survey was conducted in 2021, surveying 300 households across 11 villages within the entire study region. Finally, plot and household data were supplemented by multiple remote sensing products, such as airborne LiDAR, land cover maps and hyperspectral maps.

Most of these datasets are readily available and have been centrally deposited on the University's data sharing platform, GRO.Data. At present, the main focus of research activities is centered around analyzing and preparing publications based on these datasets. Within the EFForTS-LA framework, there are plans for a total of 26 publications, including exciting synthesis projects that aim to leverage the extensive data collected during the successful field campaign.

Under the coordination of Arne Wenzel from B09, the participating scientists continue to meet regularly maintain regular meetings to foster and strengthen their collaborations. Furthermore, a two-day statistical workshop on “upscaling” has been organized in Göttingen in early 2023. The workshop aimed to provide valuable tools and techniques for effectively utilizing the diverse datasets and optimizing their analysis.

2. Four thematic foci

Focus 1

TITLE: **Assessment of ecological and socioeconomic functions, synergies and trade-offs across different land-use systems**

REPRESENTATIVES: Ingo Grass (B09, C11), Oliver Mußhoff (C06)

RESEARCH SUMMARY:

The oil palm boom in Indonesia has had both positive and negative consequences. While it brought considerable economic benefits to rural areas, it also led to severe environmental impacts. Despite the fundamental importance of forest protection, the reality is that millions of hectares are already dominated by oil palm monocultures. Given this situation, it is urgent to focus on improving these so far overlooked habitats for reconciling trade-offs between oil palm production and conservation. In a synthesis study led by Arne Wenzel, Focus 1 specifically explored strategies to enhance biodiversity and restore ecological value while also considering the economic demands associated with oil palm cultivation. Thereby, our aim was to include as much data as possible from all oil palm systems that had been studied in the 12 years of EFForTS. To this end, a large dataset combining data on biodiversity, ecosystem functions and oil palm yields, covering smallholder plantations, industrialized company estates, and innovative experimental estates with improved agronomic management (EFForTS-OPMX) and native tree enrichment (EFForTS-BEE), was assembled. Across all these systems, we assessed biodiversity, productivity, management, and landscape structure to identify factors promoting economic-ecological win-wins.

We found that oil palm yields in industrialized estates were, on average, twice as high as in smallholder plantations (Fig. 34). Ecological indicators such as biodiversity displayed substantial variability across systems, regardless of yield variations, highlighting great potential for economic-ecological win-wins (Fig. 33).

Reducing management intensity (e.g, mechanical weeding) did not lower yields but improved ecological outcomes, making it an effective measure for balancing economic and ecological demands. Additionally, maintaining forest cover in the landscape generally enhanced biodiversity and ecosystem functioning within plantations (Fig. 35). Enriching oil palm plantations with native trees is a further most promising strategy to increase ecological value without reducing productivity (Fig. 35). In general, there

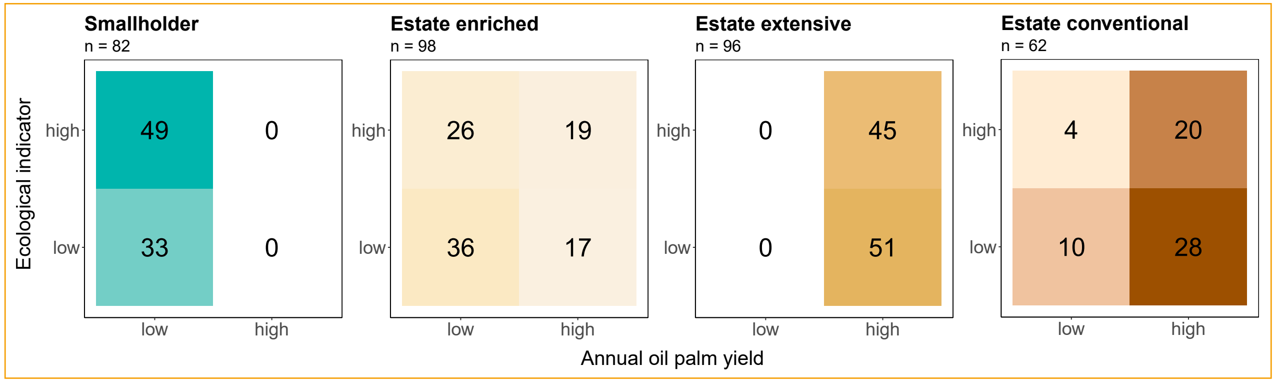
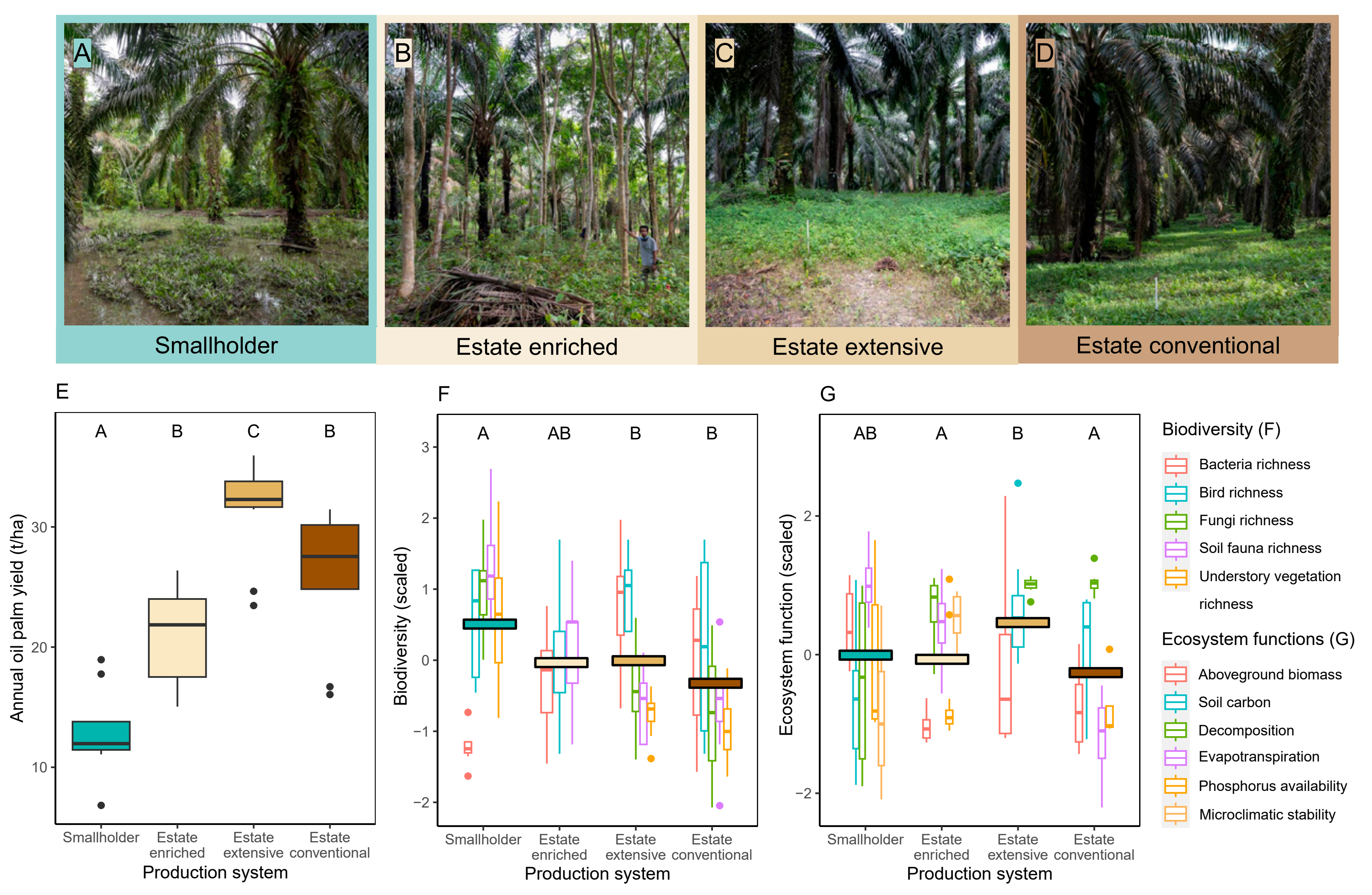


Figure 33. Contingency tables of ecological indicators of biodiversity/ecosystem functioning (y-axes) and oil palm yield (x-axes). Shown are the number of observations for indicators having a high or low value, respectively, above or below the weighted mean value of standardized indicators. Colors indicate oil palm systems, while color intensity corresponds to the number of observations per quadrant. The number of observations is displayed for each system (N_{total} = 355).



was great variability in the drivers associated with increasing yield and biodiversity/ecosystem functioning between the different taxa and ecosystem functions studied (Fig. 35). Overall, we recommend closing yield gaps in smallholder cultivation through careful intensification, whereas conventional plantations could reduce management intensity without sacrificing yield. Our study highlights various pathways to reconcile economic and ecological interests in palm oil production and identifies new management practices for a more sustainable future of oil palm cultivation.

Figure 34. Oil palm production systems considered in the synthesis study: Smallholder plantations (A), estates enriched with trees (B), estates with extensive management (C) and conventionally managed estates (D). Boxplots of mean annual oil palm yields per hectare for each system (E) and boxplots of standardized biodiversity indicators (F) and ecosystem function indicators per cultivation system (G). Boxplots represent the median (bars), the 25–75% intervals (box edges) and the 1.5 interquartile range (whiskers) of the raw data (n = 355). Boxplot colors (in F and G) indicate ecological indicator identity. Colored horizontal bars represent the mean indicator scores per system. Letters indicate statistically significant differences between systems (Tukey test, $p < 0.05$).

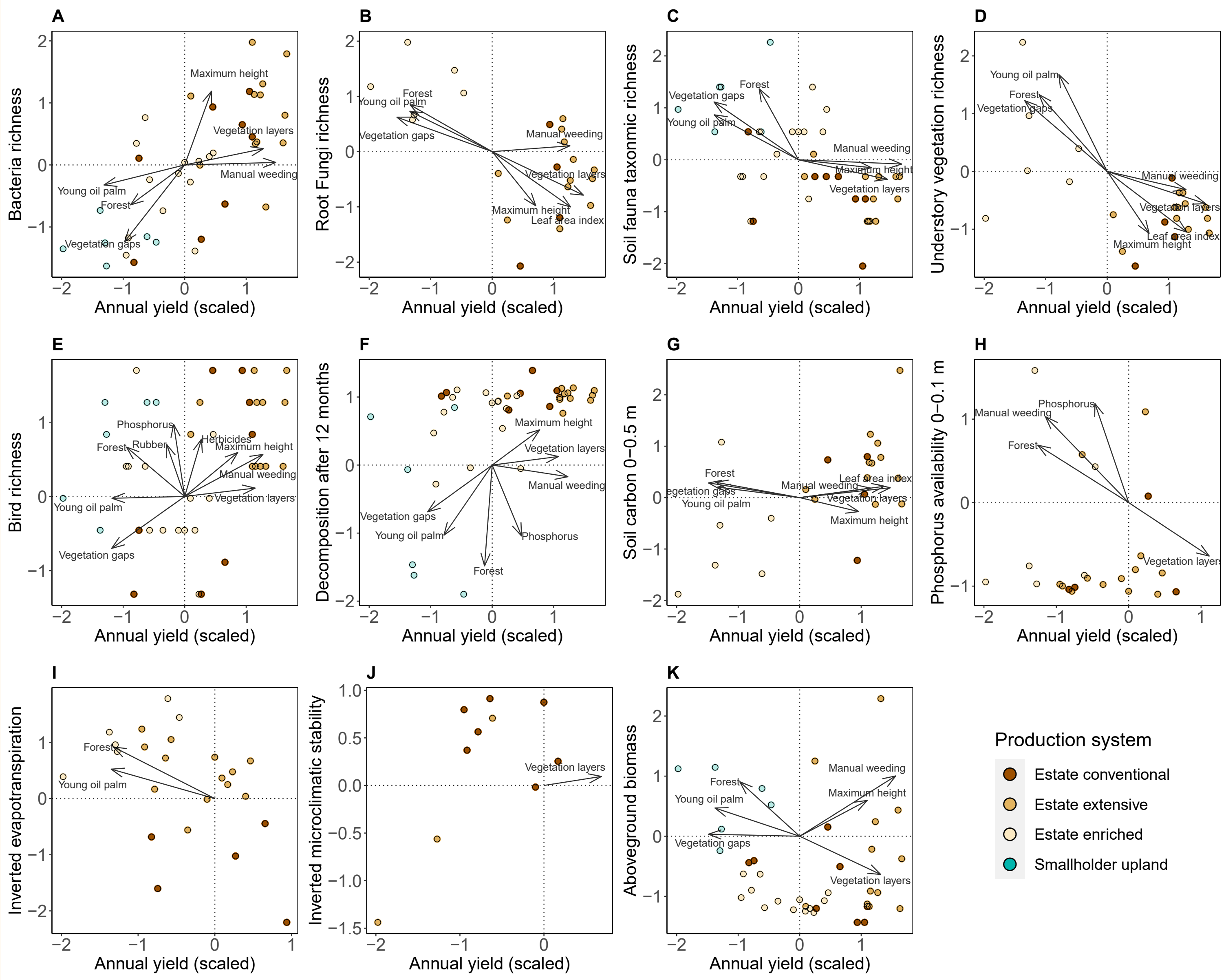


Figure 35. Variation in individual ecological indicators of biodiversity/ecosystem functions and oil palm yield across the studied oil palm systems. Shown are individual ordinations for all indicators included in the data set. Colors indicate oil palm systems. Arrows indicate plot-level structural complexity, management and landscape variables that statistically significantly ($p<0.05$) explain the two-dimensional variation in biodiversity/functions and yield. Arrow tips indicate the direction of steepest increase. Dotted lines separate win-win situations (i. e., top right quadrant) from trade-offs (top left, lower right) and lose-lose situations (lower left). Note that observations of transpiration (I) and microclimatic stability (J) have been inverted (*-1), so that high values indicate desirable outcomes. Considered predictor variables were: LiDAR metrics: Maximum canopy height (m), number of gaps, effective number of layers, i. e. structural complexity; Landscape metrics: Forest, rubber and young oil palm cover (% in a 1 km radius); Management variables: Phosphorus inputs (kg ha-1 a-1), herbicide weeding intensity (l ha-1 a-1), mechanical weeding intensity (h ha-1 a-1).

Focus 2

TITLE: **Spatial and temporal variability: Quantifying the effects of spatial, temporal and social heterogeneity on ecological and socioeconomic functions**

REPRESENTATIVES: Holger Kreft (B06, B11); Oliver Gailing (B14)

RESEARCH SUMMARY:

In natural forests, seasonal dynamics are influenced by a complex web of interactions between plants, animals, and environmental conditions. However, when forests are converted to monoculture plantations, typically dominated by a single crop species, the seasonal variation can be significantly altered. The uniformity of the plantation can lead to simplified ecological processes, reduced biodiversity, and modified patterns of temperature, humidity, and nutrient availability. Within the scope of Focus 2, research on abiotic parameters, such as soil characteristics showed that the presence of plant-available silicon, may play a role in sustaining high crop yields and enhancing the vitality and drought resistance of oil palm. In the study by Greenshields *et al.* (2023), it was found that converting rainforest into oil palm plantations for 20 years did not result in a significant depletion of soil silicon pools. This suggests that the availability of silicon in the soil can be maintained even after the land conversion. Further environmental data has revealed noteworthy spatial and temporal fluctuations in evapotranspiration within tropical rainforests across various locations and seasons. These variations in evapotranspiration are influenced by the specific conditions of each local site (Bulusu *et al.* 2023 in prep). Furthermore, to investigate seasonal and spatial dynamics of biodiversity in response to rainforest transformation to monoculture, we conducted a comprehensive examination of the decomposer system in rainforest, oil palm, and rubber plantations, exploring a wide range of soil microbial and animal data. Our results showed that both plantations displayed marked seasonal changes in microbial community indicators, with the rainforest showing almost 40% less variation than the plantations. In addition, in the litter of oil palm plantations, seasonal variation in animal abundance was 40% higher than in the rainforest, and in soil parameters about 35% higher (Fig. 36; Krashevska *et al.* 2022). Our results suggest that land use temporarily shifts and increases the magnitude of seasonal variation in below-ground ecosystem compartments, with microbial communities responding most strongly. In our litterbag study, the decomposition process in tropical rainforests and shrublands was considerably faster, resulting in a loss of approximately 66% of the mass over a 6-month period. In con-

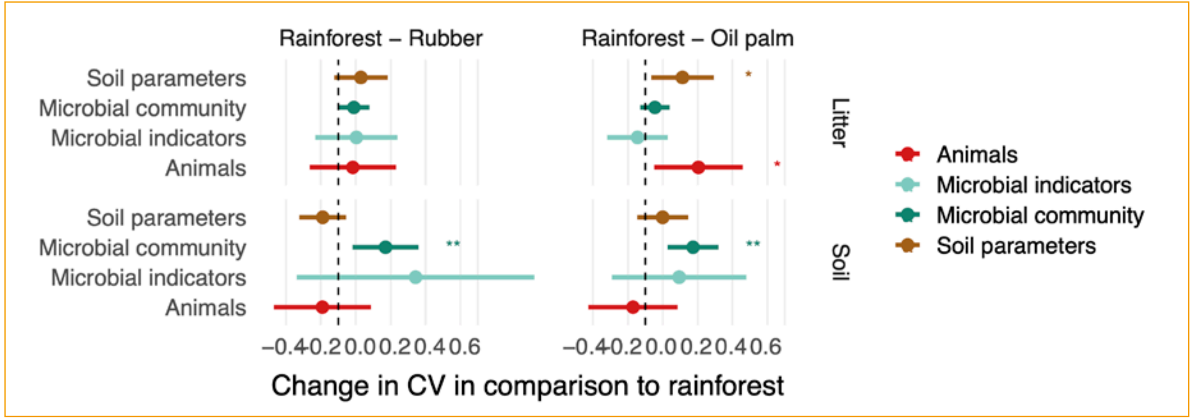


Figure 36. The magnitude of seasonal variation in soil parameters, microbial community, microbial indicators and density of animal groups in litter and soil between rainforest and rubber and rainforest and oil palm plantations. Coefficients of variation (CV) of samples are taken at four seasons. Confidence intervals that do not cross the dashed zero line indicate significant differences to rainforest (Krashevska *et al.* 2022).

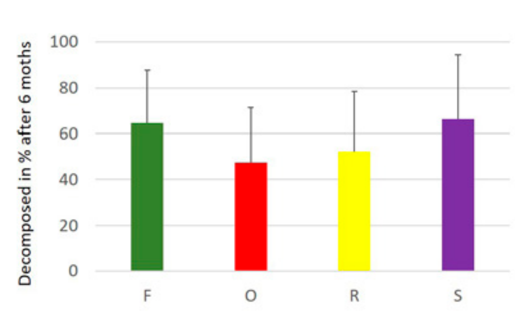


Figure 37. Litter decomposition (mass loss) in land-use assessment plots (F = rainforest, O = oil palm plantation, R = rubber plantation, S = scrubland) (Krashevska et al in prep).

trast, plantations showed a slower rate of decomposition, with a loss of about 50% of the mass over the same time period. These results show that land-use practices significantly influence decomposition dynamics and highlight the importance of considering different land uses when studying ecosystem processes in tropical lowlands at the landscape level (Fig. 37; Krashevska *et al.* in prep). Additionally, the conversion of land from rainforest to rubber and oil palm plantations leads to a significant decrease in energy flows when looking closer at canopy arthropods, reaching up to 75%. This shift in energy flows affects various trophic groups and causes changes in ecosystems. Furthermore, there are variations in the abundance of specific taxonomic groups within the arthropod assemblage, and the biomass of individual taxa also varies seasonally (Pollierer *et al.* 2023). Besides, there are additional initiatives under Focus 2 aimed at investigating the impact of landscape heterogeneity on the seasonal fluctuations of pollen loads. This collaborative research is currently being pursued by the B14 and B09 subgroups.

Overall, *Focus 2* investigates the following three *Hypotheses*:

(1) Ecological and socioeconomic functions of a given land-use system differ between landscapes, over time and by social context, i. e. statistically there are interaction effects between ecological and socioeconomic factors not only across but also within a particular land-use system.

(2) Within land-use systems, there are large differences in profitability, risk, biodiversity and ecological functions between farms and over time, and these can be explained by differences in the ecological and socioeconomic setting and/or management practices of the farm.

(3) Heterogeneity in local, regional, national and international economic and institutional conditions affects land-use change and management, and associated implications for biodiversity and ecological functions.

Focus 3

TITLE: **Scaling-up of ecological and socioeconomic functions from local to landscape and broader scales**

REPRESENTATIVES: Krisztina Kis-Katos (C10), Thomas Kneib (INF-ZfS), Catrin Westphal (B09)

RESEARCH SUMMARY:

In the final phase of CRC 990, Focus 3 activities center around exploring ecological and socioeconomic functions and trade-offs across multiple spatial scales, ranging from plot surroundings up to several kilometers to the scale of Jambi province and beyond. In the following, we summarize some of the main outcomes.

1. Remote sensing

Stefan Erasmi and Michael Schlund (Z02) with the support from researchers in different sub-groups (e.g. A03, B04, B06) used remote sensing data from various sources to upscale vegetation structures and their changes from plot to landscape level. For instance, spaceborne interferometric synthetic aperture radar (InSAR) data was used to create elevation models for the Harapan landscape for different points in time. Relying on the field surveys from 2012 and 2019, a model to estimate biomass change on landscape level was calibrated and validated.

The coefficient of determination of the model was 0.65 and the cross-validated root mean square error (RMSE) was equivalent to about 13% of the actual AGB difference range. In addition to biomass, the spaceborne InSAR data was used to estimate forest canopy height on landscape scale. The calibration of the canopy height estimation models was supported by spaceborne laser scanning data (GEDI). Finally, the canopy height estimates were validated with the airborne laser scanning data acquired in the EFForTS project. The validation revealed an error in the canopy height estimates of 37.5% with the best model. In general, it was confirmed that spaceborne remote sensing data has the potential for an accurate wall-to-wall estimation of vegetation structure in the tropical regions of Jambi, Indonesia.

2. Scale-dependent landscape-biodiversity relationships shape multi-taxa diversity

Denver T. Cayetano[1,2*], Delphine Clara Zemp, Damayanti Buchori, Sebastian Fiedler, Ingo Grass6, Dirk Hölscher[3], Bambang Irawan, Yevgeniya Korol[3], Watit Khokthong[3,4,5], Gustavo Paterno, Anton Potapov, Leti Sundawati, Catrin Westphal, Patrick Weigelt, Kerstin Wiegand, Holger Kreft, Nathaly R. Guerrero-Ramírez[1,7,8]

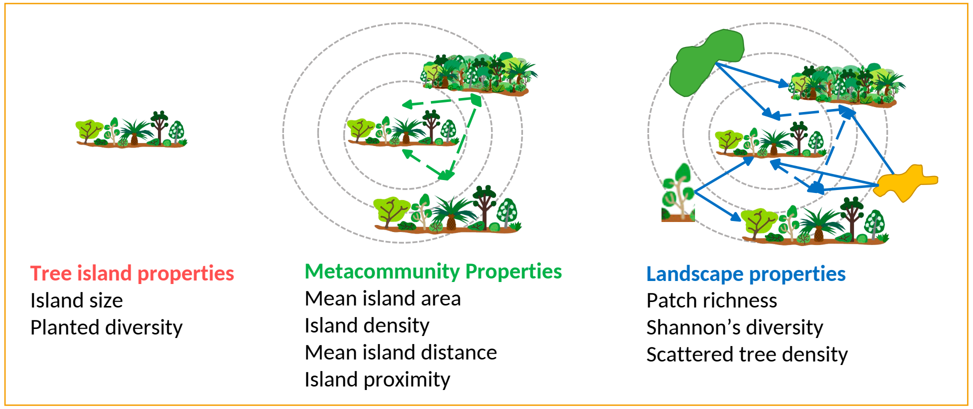


Figure 38. Based on the unified model of community assembly, it is expected that local, tree island metacommunity, and landscape properties determine the multi-taxa diversity of tree islands. The influence of metacommunity and landscape properties on the community assembly might be associated with dispersal among tree islands (internal dispersal, dotted lines) or by the combination between internal dispersal and dispersal from remnant species pools harboured by other land cover types (external dispersal, solid lines).

A major sustainability challenge is enhancing biodiversity in monoculture-dominated landscapes, without compromising agricultural productivity. Integrating tree islands within these landscapes has been shown to enhance multi-taxa diversity due to enhanced structural complexity, favourable microclimate and other local tree island properties. However, to fully understand the dynamics of this biodiversity enhancement, it is crucial to investigate the influences of the broader landscape at varying scales. Here, Denver T. Cayetano, Delphine Clara Zemp and Nathaly R. Guerrero-Ramírez (B11) supported by other members of B11 and EFForTS groups (e.g. B06, B08, B09, B10) adopt a multi-scale approach to assess the role of individual tree islands, the tree island metacommunity, and landscape properties in determining the local diversity of seven above- and below-ground taxa in 52 tree islands embedded in an oil palm-dominated landscape. Our results show that both above- and below-ground diversity are shaped by tree island (island size and planted tree diversity) and landscape properties (patch richness and scattered tree density). In contrast, metacommunity properties (mean island density, mean island area, and mean island distance) influenced mainly above-ground taxa. Across taxa, when significant, local diversity increased with island size, mean island area (excluding the focal island), patch richness, and scattered tree density; decreased with planted diversity; and either increased (for bird diversity) or decreased (for herbaceous plant diversity) with mean island distance. The scale that best predicted local diversity changed across taxa, with local diversity of trees and understory arthropods best predicted when considering smaller (150 m) and larger (700 m) spatial extents, respectively. Further, no single metric captured local diversity across taxa, highlighting the need of combining local, metacommunity, and landscape properties when designing effective, scale-conscious restoration strategies targeting increases of multi-taxa diversity in monoculture-dominated landscapes (Fig. 38)

Picture 24. The edge between a 40 x 40 m tree island (Plot 45) on the left, and a conventional palm plantation, on the right, in the EFForTS-BEE experiment, Jambi, Sumatra, Indonesia. (Picture: Gustavo Paterno, 2023).

3. A novel pipeline for assessing multi-criteria decision making models using an artificial landcover generator

Eyal Goldstein and Kerstin Wiegand (B10) have developed a novel pipeline that provides a spatial representation to theoretical land-use portfolios developed by C12 and evaluated them using animal movement models. We have taken land-use portfolios that have been generated to optimize land use for a set of indicators representing different ecological and economic functions—e.g., regulating and provisioning ecosystem services, income, and preferences—and gave them a spatial representation using the EFForTS-LGraf land-cover generator. In other words, we created artificial landscapes with land-use compositions corresponding to the portfolios of C12 that vary both in percentage of forest cover and landscape fragmentation. We then assessed these landscapes using the FunCon model, which simulates bird movement and home range accumulation in order to valuate different landscapes for the capability of supporting tropical bird communities. The entire pipeline allowed us to analyze the ecological implications of different land-use compositions and demonstrated the conditions under which portfolios optimized for ecological indicators outperform those optimized for economic indicators in supporting bird home range establishment. This novel pipeline is a good example of how to assess theoretical land-use decision making models in a spatially explicit approach, and can be further expanded by integrating other spatially explicit ecological processes. Additionally, our pipeline could further help assess ecological implications of the portfolios across different spatial scales (Fig. 39).

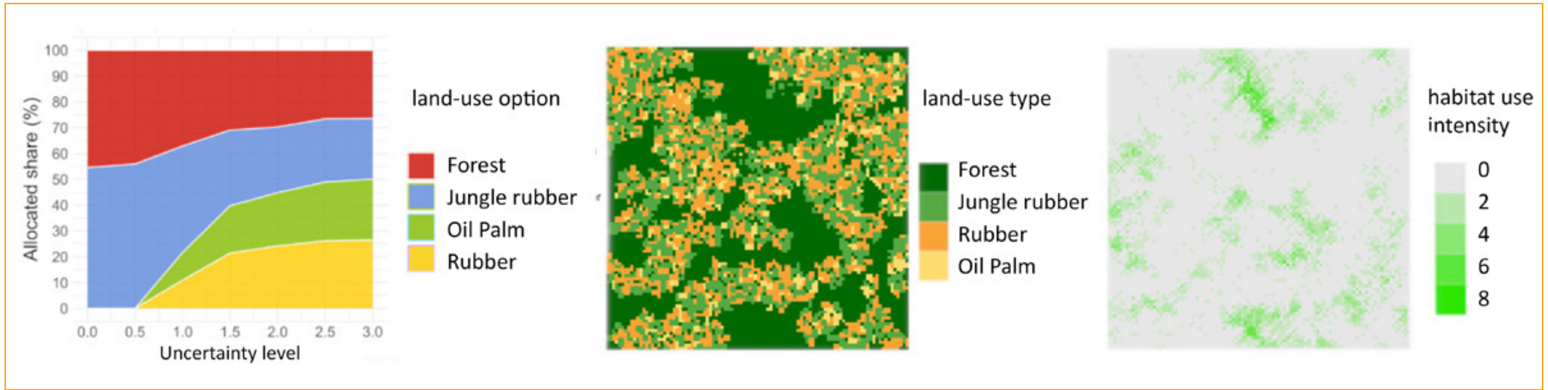


Figure 39. Illustration of the full pipeline. On the left: a portfolio demonstrating the optimal land cover composition for different uncertainty levels 0-3. In the center: an artificially generated landscape based on the portfolio of risk value of 1. On the right: a map of habitat-use intensity indicating how many overlapping bird home ranges are present on each cell. From this, one can calculate the proportion of birds being able to establish a home range in the landscape (i. e., the success rate of a bird species).

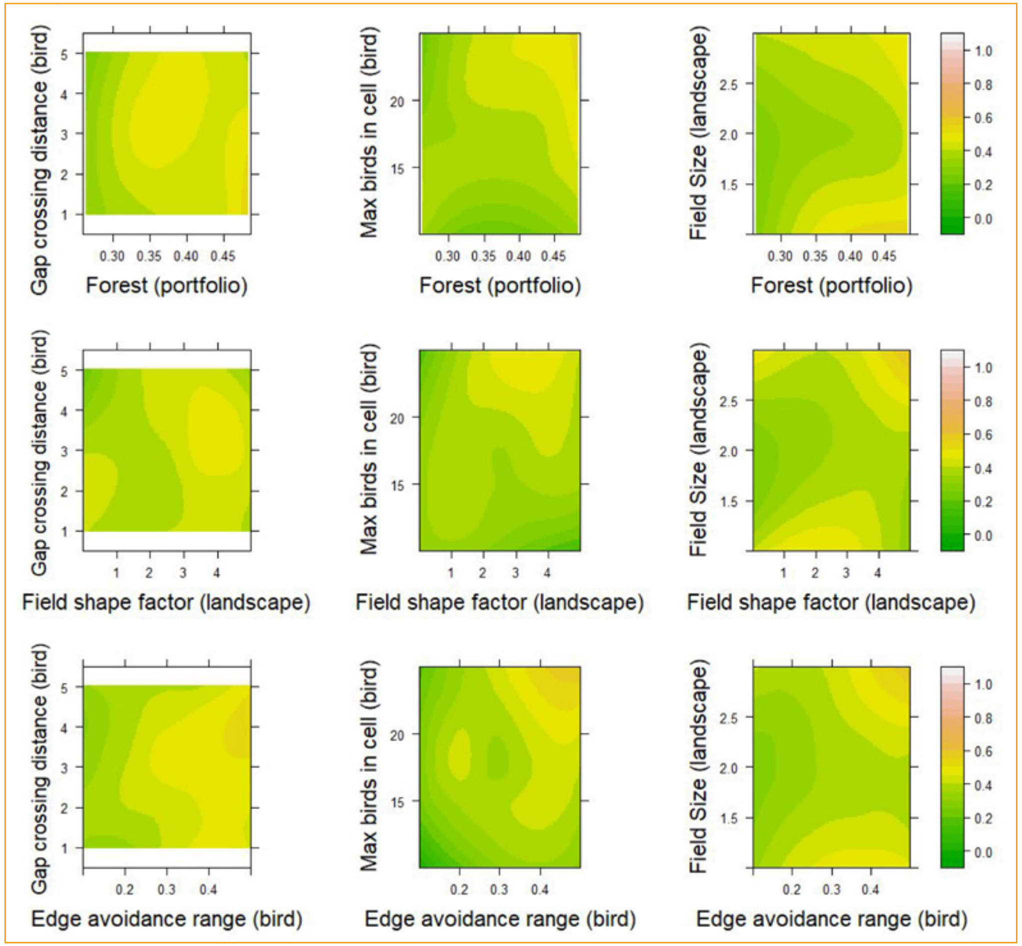


Figure 40: Interaction between parameters of different levels in the pipeline can demonstrate which types of birds are the 'winners' and 'losers' and under what landscape conditions. All factors belong to one of the pipeline levels: the land-use portfolios marked as 'portfolio', the EFForTS-LGraf landcover generator marked as 'landscape', or the FunCon bird movement model marked as 'bird'. All birds in this analysis are forest birds. Colors show their success rate (scale bars on right; explanation in Fig. 39). Left column: birds that can cross long distances between forest patches succeed the most when forest cover is medium, and forest edge avoidance is high. Middle column: allowing more birds to keep overlapping home range on each individual cell is always beneficial but has the most effect when forest cover is high and edge avoidance behavior is high. Right column: Birds are most successful in landscapes where field size is either particularly large or particularly small, but don't do well in middle values regardless of the bird or other landscape conditions.

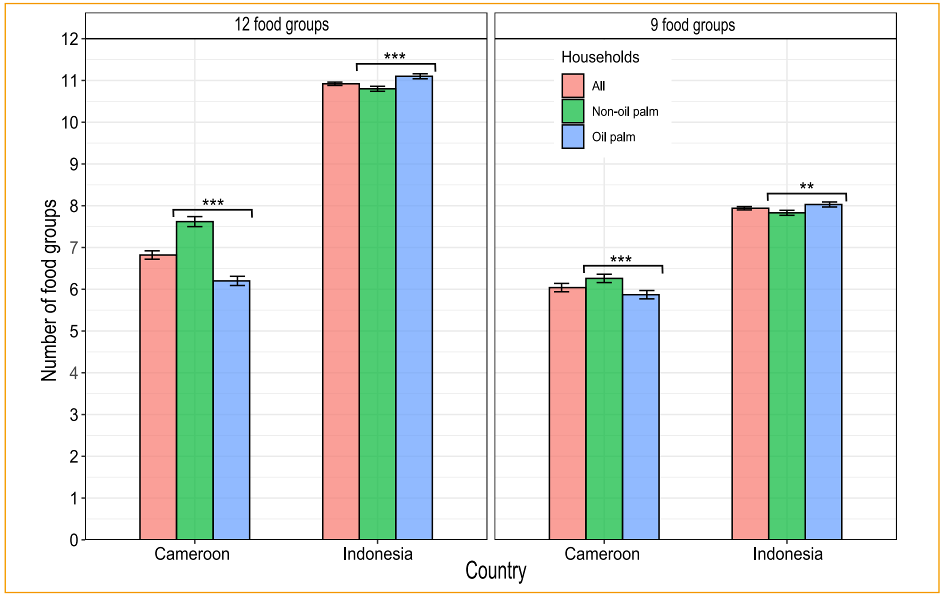


Figure 41. Household dietary diversity scores in Cameroon and Indonesia disaggregated by oil palm adoption Mean values, from group mean comparison of adopters and non-adopters, are shown with standard errors in bars. *** and ** indicate statistical significance at the 1 and 5 percent critical levels, respectively.

4. Oil Palm Expansion, Food Security and Diets: Comparative Evidence from Cameroon and Indonesia

Martin Paul Jr. Tabe-Ojong, Zulkifli Alamsyah, Kibrom T. Sibhatu (C07) study the adoption of oil palm and its relation to food security and dietary diversity for smallholder farmers in Cameroon and Indonesia where farm households continue to rapidly adopt oil palm, often at the expense of rainforests and traditional food crops. The environmental and income implications of oil palm expansion have been extensively documented, albeit primarily using data from Southeast Asia. Beyond a few case studies, research on the links between oil palm adoption, food security and dietary diversity among smallholders is scarce. This research gap is partly addressed in this study using data from Cameroon and Indonesia, two countries with different backgrounds in oil palm production, history and marketing systems. Oil palm is native to Cameroon but is an exotic crop in Indonesia that was commercialized a few decades ago. Household food insecurity experience scales and dietary diversity scores are computed, and descriptive and regression estimations are employed for the empirical analysis. Opposing results are revealed, reflecting the contextual differences between the two oil palm production frontiers. Oil palm farmers in Cameroon consume less diverse food than non-oil palm farmers. By contrast, in Indonesia, oil palm farmers perform better than their non-oil palm counterparts and consume more diversified foods (Fig. 37), possibly explaining why smallholders in Southeast Asia continue to adopt the crop rapidly. The findings also suggest that income, employment, and farm production diversity could explain the observed relationship between oil palm adoption, food security and diets. Given this, oil palm production may not be a universally suitable strategy to improve food and nutrition insecurity but may be useful in some production frontiers. Context-specific and tailored policies are needed to make oil palm cultivation and food systems more nutrition-sensitive and environment-friendly.

Focus 4

TITLE: **Towards sustainable land use in tropical lowland regions**

REPRESENTATIVES: Meike Wollni (C08, B11, C11), Carola Paul (C12)

RESEARCH SUMMARY:

Focus 4 aims to identify policy responses and scenarios that contribute to reconciling trade-offs between ecological and socio-economic functions of land use. EFForTS has contributed to an increased understanding of heterogeneities of ecosystem service provision across spatial and temporal scales in the first and second phase. EFForTS-BEE and EFForTS-OPMX provide unique data sets on oil palm management alternatives which reduce trade-offs between ecological and socio-economic functions. Yet, implementation of sustainable practices requires effective policy and/or support measures. Focus 4 integrates these different research activities and develops joint policy scenarios to derive recommendations towards more sustainable land use in Jambi.

A narrative review led by Heinrich Petri (C02), Dienda Hendrawan (C06) and Tobias Bähr (C08) highlights the challenges associated with replanting and identifies potential measures to support smallholder farmers. The process of replanting offers a unique opportunity to redesign plantations, close yield gaps, boost productivity, and secure livelihoods, if implemented correctly. Yet, due to financial and knowledge barriers, farmers often postpone replanting or use unsustainable practices. The review study finds that access to inputs, finances, and capabilities differ greatly between different groups of smallholders, likely affecting the decision of when and how to replant. Relevant Information on replanting, proper training, access to high-quality seedlings, as well as eligibility for public replanting funds are determinants of successful smallholder replanting efforts in Indonesia but are currently distributed unevenly.

A study led by Kibrom Sibhatu (C07) systematically reviews the effects of Roundtable on Sustainable Palm Oil (RSPO) Certification on the environment, oil palm yields, and human welfare, as well as the factors that determine its adoption by smallholder farmers. The findings show that obtaining RSPO certification positively affects input use and promotes oil palm productivity, but exacerbates asymmetric power structures in land rights and scheme decisions. RSPO certification has increased the number of family members engaged in agricultural wage labor, but is also associated with altering traditional family farming systems. The study concludes that to promote sustainable palm oil production practices among smallholders, efforts must be made to increase the benefits of RSPO certification, while at the same reducing the costs of certification and addressing socioeconomic and farm issues that hinder adoption.

In the integrative project C11, Anette Ruml coordinates an integrated policy analyses at an aggregated scale using a Social Accounting Matrix (SAM). This matrix captures all the economic activities within a stylized local rural economy, including a large-scale plantation, an oil palm processing mill, and multiple neighboring villages that contribute agricultural labor and oil palm fresh fruit bunches. Employing this data framework, which captures the interlinkages between sectors and stakeholders, allows to examine plot- and household-level data and experiments (such as RSPO certification, OPMX, and EFForTS-BEE) at an aggregated scale.

In another modelling effort, Sebastian Fiedler (B10) and Adriana Bernál-Escobar (C08) are working on the integration of experimental data collected by C08 into the EFForTS-ABM developed by B10, in order to scale up to the landscape level the cost-effectiveness analysis of PES schemes for enrichment planting in oil palm plantations. The main objective of this collaboration is to identify which PES policy designs achieve the greatest ecological outcomes at the lowest socioeconomic cost (i. e., mitigating trade-offs between ecological and socio-economics functions). In particular, it focuses on analyzing the effect of using different payment levels, payment distributions

Picture 25. The transition team of Pematang Kabau in March 2022.

and of incentivizing spatial coordination in the enrichment of oil-palm plantations. The main contributions lie in the extension of the behavioral function of agents to include intrinsic values and motivations, in addition to the economic logic; and in the construction of a network parallel to the social learning network, which captures the level of connectivity of the enriched oil palm plantations. In the last months, MSc student Niamh Halmschlag has been reviewing the literature on PES-ABM integration to develop a conceptual model to help incorporate these two features into the current model.

With additional support from Documenta 15, C08 has engaged in the "Sustainable Village Project" that aims to explore transition pathways towards more sustainability using a participatory approach. Employing the community arena approach to transition management, Immanuel Manurung and Jana Juhrbandt (C08) have been exploring and implement-

Picture 26. Participants during a participatory visioning exercise using village maps.

Picture 27. Transition team on field excursion: Pak Bambang Irawan (UNJA) explaining the biodiversity enrichment experiment (B11).

ing sustainable land use and value addition practices with smallholder farmers in Pematang Kabau village. The goal is to balance economic prosperity with the restoration and protection of ecological functions and biodiversity. Using an action research methodology, the project aims to initiate a shared learning process between the researchers and a network of local pioneers (community arena transition team), creating a space for planning and testing sustainability innovations.

The transition team was formed in the creative atmosphere of the Semabumi Festival in March 2022. Most of the participating villagers are involved in palm oil production. Participatory visioning and problem analysis exercises helped with case orientation, and video documentation of the workshops and additional short interviews were shown in the Göttingen Forum Wissen special exhibition "Saujana Membumi" in summer 2022. An important part of the action component in this research consists of capacity building activities, such as an excursion to the EFForTS-BEE plots in October 2022, and a workshop on proposal writing for project funding in March 2023. The research accompanying the "Sustainable Village Project" will provide insights into the factors facilitating and hindering transition processes towards more sustainable land use.

III. ABS – Biodiversity Research, Access to Genetic Resources and Benefit Sharing (ABS)

1. **Research projects of counterparts and stakeholders in 2022/2023**
2. **Scholarships for early career researchers of counterparts and stakeholders**
3. **Capacity building workshops**
4. **Publications**

The Convention on Biological Diversity (CBD) is a multilateral treaty dedicated to promoting sustainable development. It was signed by 150 government leaders at the 1992 Rio Earth Summit (Brazil). CBD has three main goals: the conservation of biological diversity (or biodiversity), the sustainable use of its components, and the fair and equitable sharing of benefits arising from genetic resources.

The Nagoya Protocol on *Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization* (ABS) to the Convention on Biological Diversity is a supplementary agreement to the Convention on Biological Diversity. It is the legally binding mechanism to implement access and benefit sharing. Both Germany and the EU signed it on 23 June 2011 and the Republic of Indonesia on May 11, 2011.

The Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) is one of the few funding agencies around the world that has implemented (since 2008) its own Guidelines to promote the application of the principles and procedures of ABS among its applicants (see article 8a[1] of the Nagoya Protocol, *https://www.cbd.int/abs/text/*). In 2013, DFG approved funding of ABS measures with central research funds of the CRC 990, and since November 2013, *EFForTS* supports the project partners in Indonesia.

In Phases 1 and 2 (2012–2019), EFForTS awarded

- 108 short-term research grants to counterparts and stakeholders (LIPI, PTPN VI, PT Humusindo, BKSDA, PT REKI, Ministry of Forestry) to strengthen the research cooperation
- 13 research grants and scholarships for early career researchers of counterparts and stakeholders
- Set up of a research station at PT. Humusindo, a field laboratory at the National Park Bukit Duabelas and a herbarium at UNJA.
- 3 capacity building workshops at partner universities in Indonesia

In Phase 3 (2020–2023), we continued to support our partners in Indonesia. To date we

- Awarded 52 research grants for counterparts and stakeholders
- Awarded 15 scholarships and extended two from Phase 2
- Granted 19 capacity building workshops
- Support(ed) the education of two master students of stakeholders (PT REKI and TNBD)

1 Nagoya Protocol, article 8a. Special considerations: Create conditions to promote and encourage research, which contributes to the conservation and sustainable use of biological diversity, particularly in developing countries, including through simplified measures on access for non-commercial research purposes, taking into account the need to address a change of intent for such research.

1A. ABS – RESEARCH PROJECTS OF COUNTERPARTS AND STAKEHOLDERS IN 2022

SUMMARY REPORTS OF FUNDED ABS PROJECTS IN 2022

IPB University
Bogor Indonesia

Research projects of counterparts funded at IPB

Name	Counterpart	Title
Tiara Sayusti, Rika Raffiudin, Nina Ratna Djuita, Windra Priawandiputra	**A01**	Pollen diversity in honey revealed the foraging preference of the sympatric honey bee and stingless bee

Research Summary

Resource partitioning is essential to regulate competing community species to use the same resource at different places and times Pringle, 2021), it can stabilize the coexistence of species and maintain biodiversity. Resource partitioning was observed between the eusocial honey bee (*Apis mellifera*) and the stingless bee (*Melipona quadrifasciata*) in Brazilian rain forest (Wilms & Wiechers, 1997), where *M. quadrifasciata* collected pollen less diverse compared to *A. mellifera*. The research also found that the same resources were collected at different times.

Melissopalynology in stingless bee honey of *Heterotrigona itama* and *Tetragonula laeviceps* from Belitung Island revealed that the smaller-sized stingless bee *T. laeviceps* collected more diverse pollen compared to *H. itama* (Priambudi *et al.* 2021). Thus, we aimed to analyze the melissopalynology of pollen from honey to reveal the resource partitioning of the sympatric honey bee and stingless bee species in the high- and lowland.

We used honey bee *A. cerana* and the stingless bee *T. laeviceps* at the highland of Gunung Puntang Bee Learning Centre, Bandung Regency, West Java (1.258 m asl) and *A. cerana* and *H. itama* in the lowland of Flora Nauli bee farm in Pematang Siantar, North Sumatra (445 m asl). Honey from the observed bees was collected for melissopalynology. Pollen was extracted from honey and analyzed using acetolysis solution (Erdtman, 1972). Pollen identification was conducted based on APSA (*https://apsa.anu.edu.au/*). Pollen types and composition from the honey were determined for a minimum of 300 pollen grains.

A total of 13 pollen types were identified from the honey samples from the highland (Fig. 42A) and 14 pollen types from the lowland (Fig. 42B). Based on the pollen diversity in honey, we found that *A. cerana* collected pollen from less diverse flowers than *T. laeviceps* in the highland (Fig. 43). Both *A. cerana* colonies only collected two pollen types. *Ageratum* sp. dominated the first colony, while the second colony was dominated by Euphorbiaceae-3

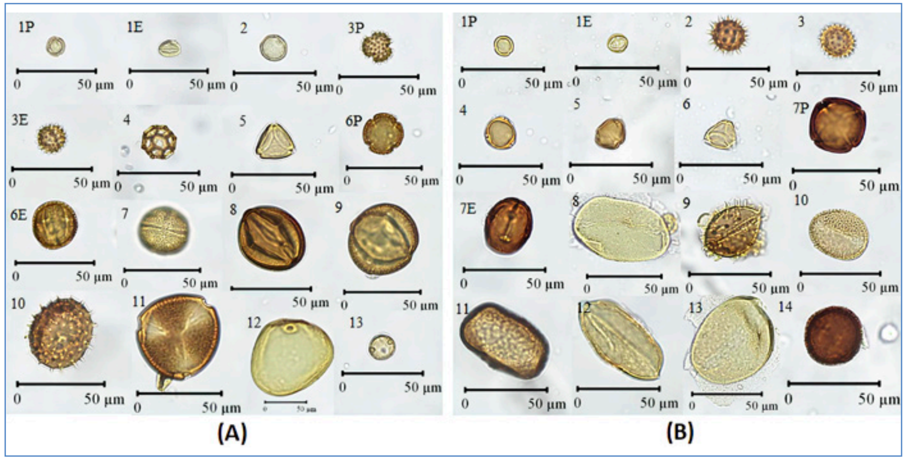


Figure 42. Pollen diversity is contained in the honey of sympatric honey bee and stingless bee species. **(A)** Stingless bee *T. laeviceps* and honey bee *A. cerana* in the highland: 1) Fagaceae; 2) Urticaceae/Moraceae type; 3) *Ageratum* sp.; 4) Asteraceae; 5) *Eucalyptus* sp.; 6) *Glochidion* sp.; 7) Euphorbiaceae-1; 8) Euphorbiaceae-2; 9) Euphorbiaceae-3; 10) Convolvulaceae; 11) Euphorbiaceae-4 type; 12) Poaceae; and 13) Sp.1. **(B)** Stingless bee *H. itama* and honey bee *A. cerana* in the lowland: 1) Fagaceae; 2) *Ageratum* sp.; 3) Asteraceae; 4) *Fagus* sp.; 5) *Ziziphus* sp.; 6) *Syzygium* sp.; 7) *Mimusops* sp.; 8) *Cocos nucifera*; 9) *Arenga* sp.; 10) Arecaceae-1; 11) Arecaceae-2; 12) Arecaceae-3); 13) Arecaceae-4; 14) Sp.2. Scale bar = 50 µm; P = Polar; E = Equatorial.

(Fig. 43A). In contrast, the pollen collected by *T. laeviceps* was more diverse (13 pollen types from seven different families), i. e., Euphorbiaceae, Poaceae, Myrtaceae, Asteraceae, Urticaceae/Moraceae type, Fagaceae, Convolvulaceae, and one unidentified pollen. The first colony was dominated by *Glochidion* sp., while the second colony was dominated by Asteraceae (Fig. 43B). The pollen of Euphorbiaceae-3 was found in all honey samples of *A. cerana* and *T. laeviceps* (Fig. 43A-B), which indicates that *A. cerana* and *T. laeviceps* also shared the same pollen resources. While the pollen type of Urticaceae/Moraceae was only collected by *T. laeviceps* colonies (Fig. 43B).
Consistent with the highland results, the lowland *A. cerana* also collected pollen from less diverse flowers than *H. itama* (Fig. 43C). Apis cerana honey contained three pollen types from a single family Arecaceae and was dominated by *Arenga* sp. (Fig. 43C). In contrast, *H. itama* collected more diverse pollen from several plant families, i. e., 11 pollen types from six different families (Asteraceae, Arecaceae, Fagaceae, Sapotaceae, Rhamnaceae, Myrtaceae, and one unidentified family). *Ageratum* sp. dominated the first colony, while the second colony was dominated by *Cocos nucifera* (Fig. 43D). In the lowland, each colony of honey bee *A. cerana* and stingless bee *H. itama* have specific pollen resources. Pollen of *Ageratum* sp. was shared between *H. itama* colonies, while pollen of *C. nucifera* was shared at the intra- and inter-species level.
In summary, both in the high- and lowland, stingless bee honey contained more diverse pollen types than honey bees. Stingless bee *T. laeviceps* and *H. itama* have a smaller body size compared to honey bee *A. cerana*. Body size facilitates resource partitioning of organisms with the same food resources (Schoener, 1974). Stingless bees visit more diverse flowers with small and narrow petals, due to their small body size (Engel & Bakels, 1980). Thus, different body size provides different niches, which allow sympatric species to coexist stably by decreasing the likelihood that one species will deplete the resources needed by another. We conclude that stingless bees *T. laeviceps* and *H. itama* utilized a higher diversity of pollen resources than the honey bee *A. cerana* in the high- and lowland and each colony showed preferred pollen types.

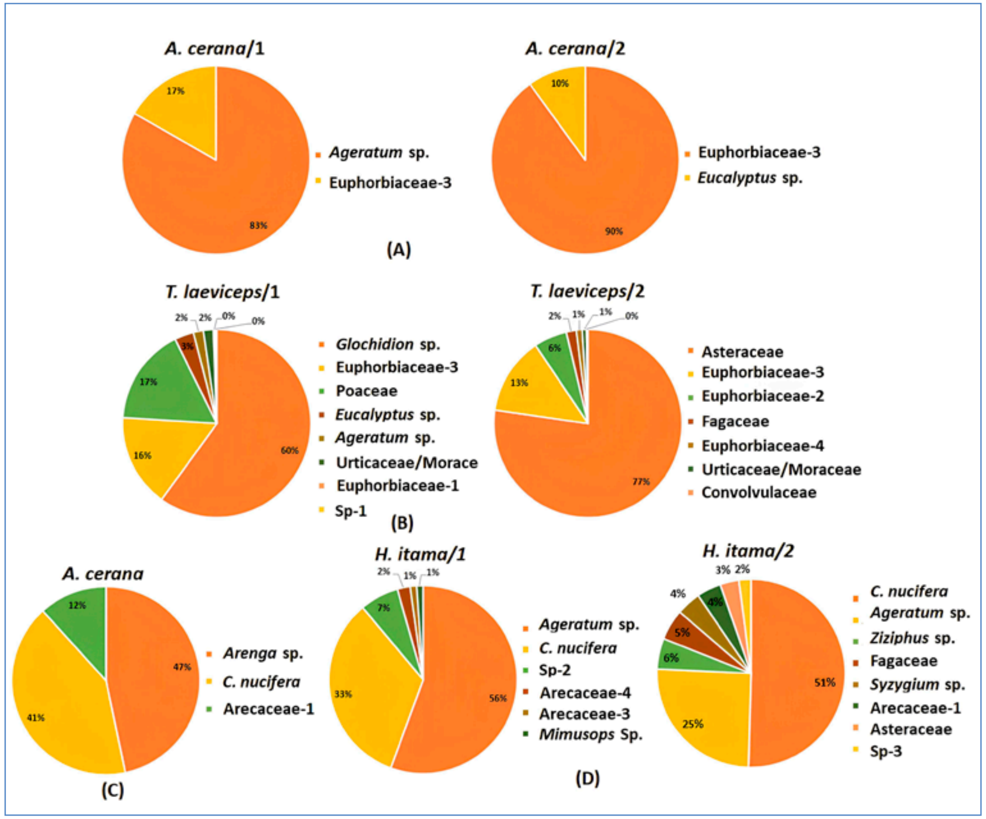


Figure 43. Pollen composition contained in honey from highland and lowland. (A) A. *cerana* highland, (B) T. *laeviceps* highland, (C) A. *cerana* lowland, and (D) H. *itama* lowland.

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Herdatha Augusta	A02	Variability of infiltration rates under different understory vegetation in oil palm during the wet and dry season

Research Summary

There is limited information on the impact of understory vegetation, especially of moss which grows extensively in oil palm plantations, on soil infiltration and moistening, and its contribution to improve ecosystem service. The objective of this study was to identify the role of understory vegetation – moss and weeds – on cumulative infiltration rates and infiltration capacities during the wet and dry season in mineral soils (terrestrial area) and riparian areas of oil palm plantations of smallholder and corporate farmers.

The study was conducted at a) HOR3 at Sungkai (riparian area, age of plantation of 12-16 years) and at PTPN VI, and b) at HOR2 at Singkawang & PTPN VI (mineral soil).
The destructive area outside of the core plots area was selected as the observation point. Data collection took place in the dry season (August-October 2022) and the rainy season (October-December 2022). The observation frequency was conducted three times in the rainy season and twice in the rainy season. The observation area was situated in a riparian zone in PTPN6 with a distance to the water body of less than 40m and HOR3, and a terrestrial area with a distance to the water body of more than 40m in PTPN6 and 3 oil palm smallholder farmers in Singkawang, Kabupaten Batanghari. The sampling area represents each oil palm distance spacing at 9 m x 9 m x 9 m considering the contribution of the circle area and active path area. Vegetation that emerged at the frond pile area was not observed.
The measured parameters are the following: 1. Soil covering rate with weeds and moss, 2. cumulative infiltration rate in 4 hours in the first infiltration time and infiltration capacity (K_s) with manual double-ring infiltrometer.

At the area where minimum sunlight transmission (5–10%), i.e., at the circle area in a radius of ±1.6m around the oil palm trunk, it was found, that the moss growth in the riparian area was more intensive in the dry season rather than in rainy season (Table 3). On the contrary in the same season, the weed growth showed the lower dominancy against the most growth. The main concern at the active path area of the oil palm plantation at the riparian zone in the rainy season showed a similar occurrence, where the growth of mosses covered approximately 312% compared to the weed cover rate. The total covering rate of both vegetation amounted to 61.7%. In the active path of terrestrial area weed growth dominated the surface cover of oil palm plantations in both seasons, where the cover of weeds reached 67.8% and moss covers at the level of averagely 11.3%. The total covering rate by the vegetation was 79.1%, and 20.9% of the surface area was without any vegetative protection.

Table 3. Moss and weed covering rate at the riparian area and terrestrial area in dry and rainy season oil palm plantation.

Area	Cover	Surface covering rate (%)			
		Dry Season		Rainy Season	
		Circle area	Active path	Circle area	Active path
Riparian	Moss	55±22	36±16	32±27	46±17
	Grass	13±6	30±7	14±9	15±17
Terrestrial	Moss	21±17	8±4	3±5	14±6
	Weed *	38±16	70±6.	39±12	67±10

*± (standard deviation)

In the riparian area, there was no evidence of the difference of infiltration rate measured in Ks both in the circle area and active path area, which reached very low at the value of 1.74-4.02 cm h^{-1} in the dry season and 3.29-3.88 cm h^{-1} in the rainy season (Table 4). However, in the terrestrial area at the active path area, the Ks value reached an average of 12.13 cm h^{-1} in the dry season and 5.86 cm h^{-1} in the rainy season. The Ks-value in the oil palm circle in the terrestrial area showed no difference value, which was a very low category value ranging from 3.37-3.80 cm h^{-1}. The cumulative value of infiltrated water during the first four hours in the riparian zone in the active path ranged from 10.35-18.52 cm. This value is lower than cumulative infiltrated water in terrestrial areas, which ranges from 25.83-110.55 cm in the first 4 hours of infiltration time.

Table 4. Infiltration rate at the circle and active path area of oil palm in dry and rainy seasons in categorized riparian and terrestrial zone

Categorized zone	Season	Infiltration rate	Circle area	Active path
Riparian area	Dry season	K_s-value (cm h^{-1})	4±2	1±0.27
		Cum. infiltration (cm)*	22±10	10±1
	Rainy season	K_s-value (cm h^{-1})	3±0.90	3±1
		Cum. infiltration (cm)*	20±1	18±4
Terrestrial area	Dry season	K_s-value (cm h^{-1})	3±0.67	12±9
		Cum. infiltration (cm)*	33±7	110±20
	Rainy season	K_s-value (cm h^{-1})	3±0.97	5±2
		Cum. infiltration (cm)*	17±2	25±10

*Cumulative infiltration value in 4 hours infiltration time; ± (standard deviation)

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Tania June	**A03** **A07**	Spatial analyses of oil palm evaporation: Correlation matrix with micrometeorological driving forces

Research summary

This research aims to estimate the spatial distribution of oil palm evapotranspiration and its correlation with micrometeorological variables and to increase the accuracy of spatial evapotranspiration determination by hot and cold pixel selection using the METRIC Model. Evapotranspiration was determined at various oil palm ages using Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC) model, where the calculation of energy balance components is going to be corrected using hot and cold pixels. Landsat imagery, climate data obtained from ERA-5 reanalysis, and micrometeorological data from PTPN VI are used to calculate NDVI, land surface temperature (Ts), surface albedo, emissivity, and roughness length, where thereafter, energy balance components, i.e., net radiation (Rn), ground heat flux (G), sensible heat flux (H), and latent heat flux (LE) were determined and were used to estimate the daily evapotranspiration of oil palms. The output was evaluated and validated using observed data from micrometeorological measurements in PTPN VI Jambi Province. Total area of PTPN VI Batang Hari is 2186 Ha. The area of each afdeling I, II, and III are 676 Ha, 772 Ha, and 577 Ha. Areas of oil palm planted in 1999, 2002, and 2004 are 600 Ha, 1400 Ha, and 25 Ha, respectively (Fig. 44).

Validation of the output model was conducted using the Penman-Monteith (PM) method calculated from the micrometeorological data from the on-site climate tower in PTPN VI Batang Hari. The observation data used in the validation process were point data therefore buffer analysis is carried out to validate various distances of spatial ET (Fig. 45). The comparison of the Root Mean Square Error (RMSE) average between daily ET from the model output and ET-PM shows = 0.19 mm d^{-1} (without pixel selection) and = 0.16 mm d^{-1} (with pixel selection) showing that model output with pixel selection can determine ET more accurately than without pixel selection. Using average data for 2015 and 2016 (with pixel selection) a micrometeorological driving forces correlation matrix for the daily pattern was developed. Between Evapotranspiration ET with rainfall (P), air pressure (P), wind speed (Ws), relative humidity (RH), air temperature (Ta), soil temperature (Tsoil), soil moisture (SM), net radiation (Rnetto), ground heat flux (G), actual vapor pressure (e_a), sensible heat flux (H), latent heat flux (LE), LE-H, Bowen ratio (β). Each relationship between variables was estimated by Pearson's correlation coefficient. ET was strongly influenced by Rn and LE-H shown by positive correlation coefficients of 0.85 and 0.95 while H and β influenced ET with negative correlation coefficients of -0.63 and -0.75 respectively. β is strongly correlated with H shown by a positive correlation coefficient of 0.84, while SM, LE-H, and ET have a negative correlation with β shown by r= -0.58, -0.85, and -0.75 respectively. A high positive correlation between β and H shows that biophysically if Rn is allocated more to H, it will decrease ET since H is used for heating up surrounding air and increasing temperature, while LE biophysically used by the ecosystem to transform water into vapor, and reducing the tempera-

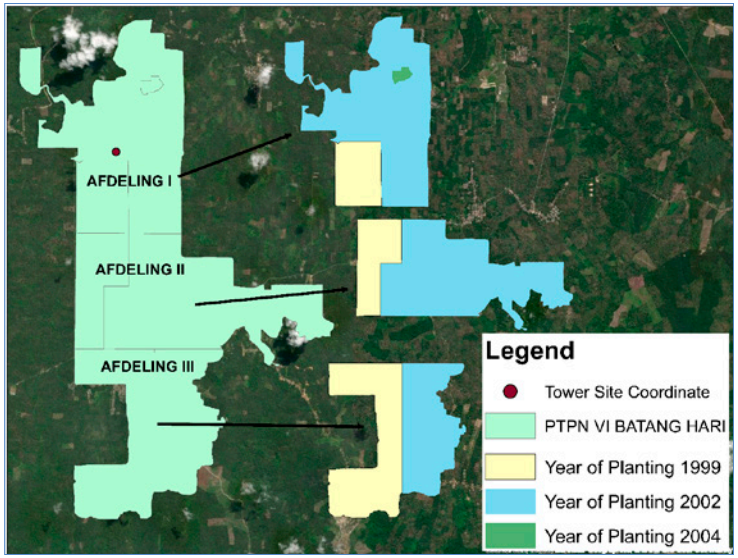

Figure 44 shows the daily spatial evapotranspiration in different planted years with and without pixel selection. For acquisition imagery August 2015, it shows that without pixel selection the means ± standard deviation of daily evapotranspiration for oil palm planted in 1999, 2002, and 2004 were 2.25 ± 0.49 mm d^{-1}, 2.24 ± 0.49 mm d^{-1}, and 2.25 ± 0.27 mm d^{-1} while with pixel selection 2.38 ± 0.19 mm d^{-1}, 2.37 ± 0.19 mm d^{-1}, and 2.34 ± 0.09 mm d^{-1}, respectively. Daily evapotranspiration in July 2016 without pixel selection for oil palm planted in 1999, 2002, and 2004 were 4.20 ± 1.08 mm d^{-1}, 4.23 ± 1.11 mm d^{-1}, and 5.12 ± 0.00 mm d^{-1} and with pixel selection 4.69 ± 0.47 mm d^{-1}, 4.71 ± 0.47 mm d^{-1}, and 5.12 ± 0.01 mm d^{-1}, respectively.

ture, that is why LE–H had strong positive correlation coefficient with ET. The correlation coefficient also shows that Rn is allocated more to LE rather than H, this indicates that in PTPN VI, available energy is prioritized to transform water into vapor rather than heating up surface air temperature, indicating water availability in the region is sufficient.

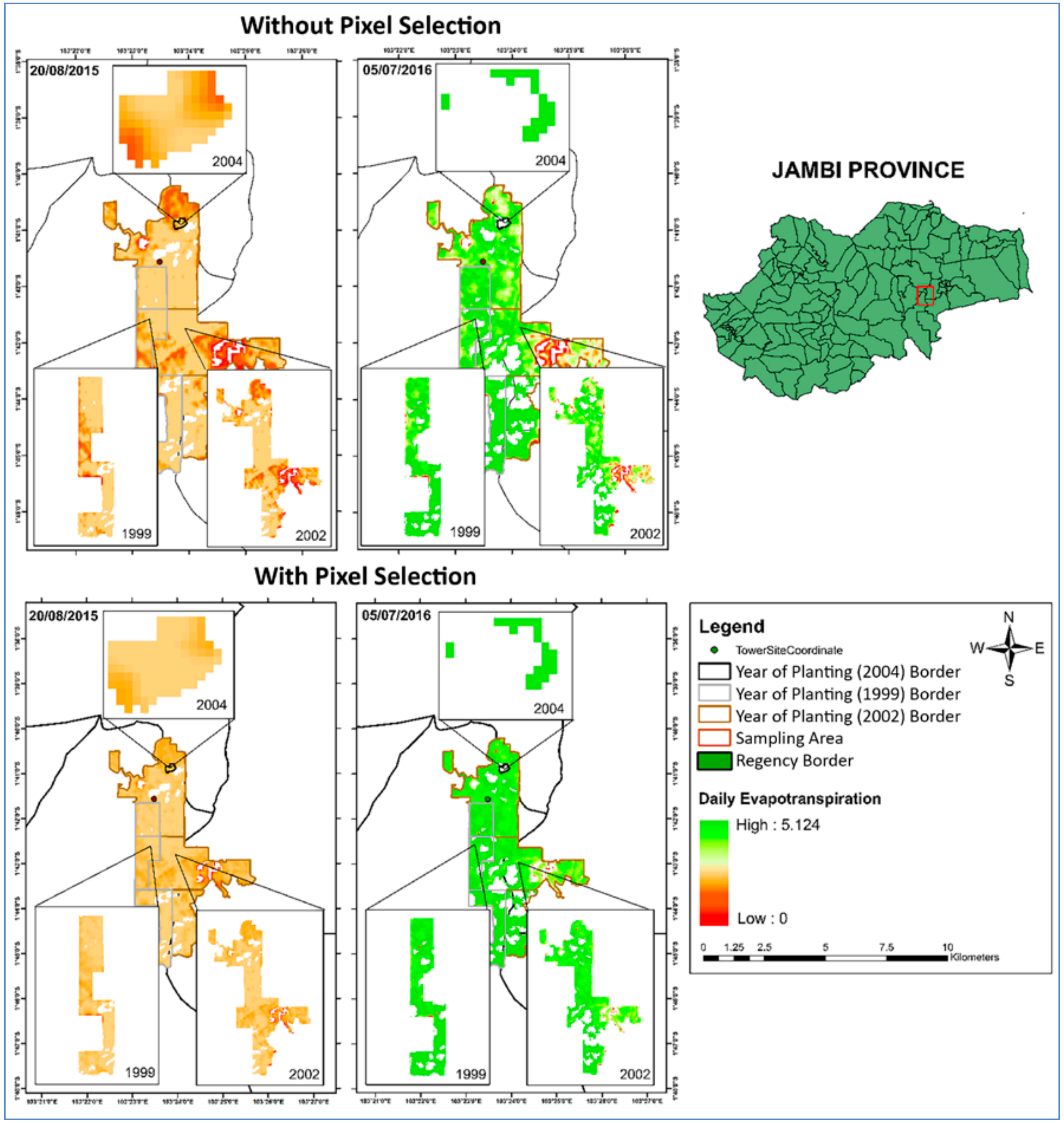

Figure 45. Distribution of spatial daily evapotranspiration in oil palm plantation PTPN VI Batang Hari, Jambi Province

Triadiati, Evan Vria Andesmora	**B04**	Growth and Photosynthetic Rate of Jambi Oil Palm Seedling Accessions Treated by Different Waterlogging Durations

Research summary

Oil palm plays a major role in Indonesian economic development, particularly in Jambi Province. The economic benefits offered by the palm oil sector have significantly aided Jambi's economy, including increased farmer income, employment creation, and increased local revenue. Cultivated land is also frequently seen on sloping terrain. Cultivation on steep slopes might result in significant waterlogging. Rainwater trapped in hollows can cause the soil to become overly moist, causing root damage and plant damage. So, it will cause physiological conditions and development in oil palm plants to be less than optimal. This research is expected to provide information about accessions that have good adaptability to waterlogging.

To investigate those parameters, we conducted research in a greenhouse at IPB University. We used a factorial complete randomized block design with the accession of 3 months old oil palm seedlings from Muara Jambi (MJ), Tebo (TB), Tanjung Jabung Barat (TJB), Merangin (MR), and Simalungun (SM). The waterlogging treatments were carried out at two, four, and six weeks with three replications for each treatment. The water level is 2 cm above the surface of the soil. Measurements of photosynthetic rate were made on the mature leaves using Li-Cor 6400. Oil palm seedlings were harvested for fresh and dry weight.

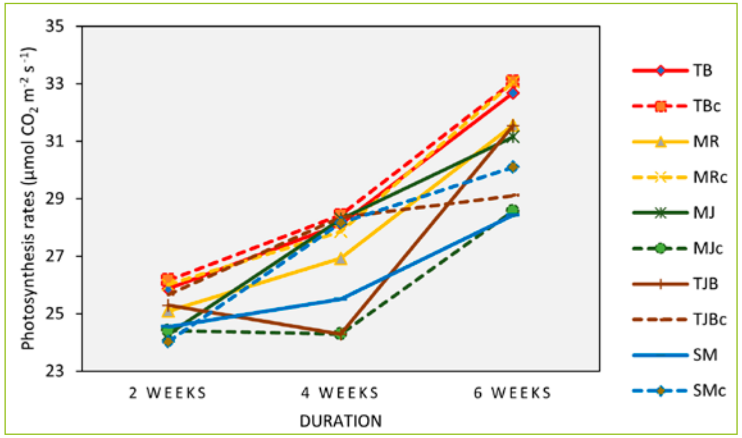

Figure 46. Photosynthetic rate of oil palm Jambi accessions treated by different waterlogging durations. *(MR: Merangin, MR Con: Merangin Control, SM: Simalungun, SM Con: Simalungun Control, TJB: Tanjung Jabung Barat, TJB Con: Tanjung Jabung Barat Control, TB: Tebo, TB Con: Tebo Control, MJ: Muara Jambi, MJ Con: Muara Jambi Control)*

Based on data on photosynthetic rate (Fig. 46), increase in fresh weight, and dry weight (Fig. 47), the Tebo accession of oil palm seedlings can grow well up to 6 weeks of waterlogging.

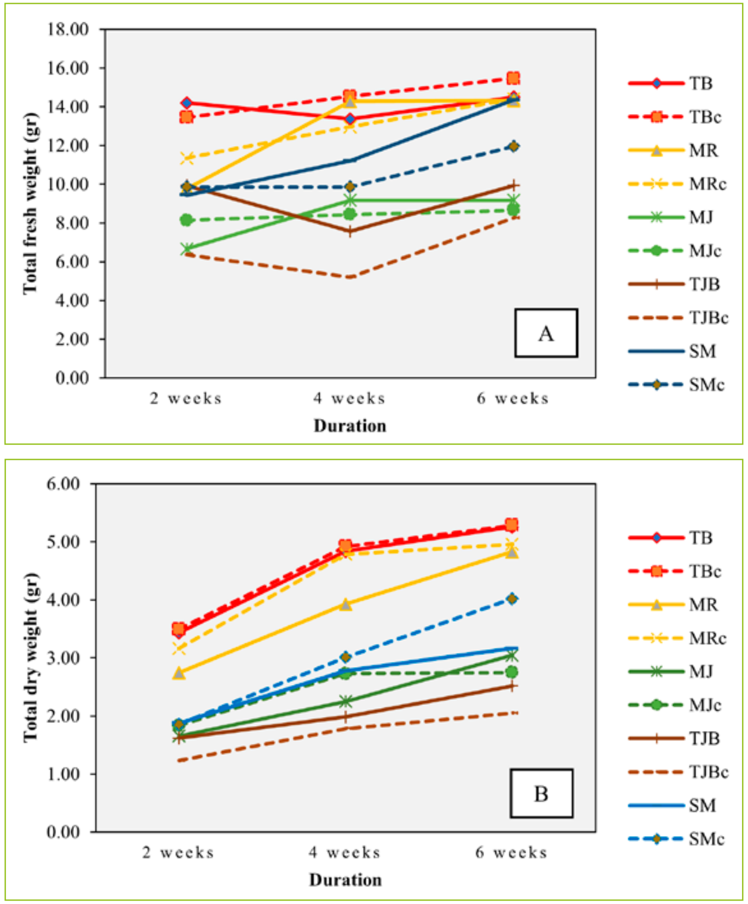

Figure 47. Total fresh weight **(A)** and dry weight **(B)** of oil palm seedlings from Jambi accessions treated by different waterlogging durations. *(MR: Merangin, MR Con: Merangin Control, SM: Simalungun, SM Con: Simalungun Control, TJB: Tanjung Jabung Barat, TJB Con: Tanjung Jabung Barat Control, TB: Tebo, TB Con: Tebo Control, MJ: Muara Jambi, MJ Con: Muara Jambi Control)*

Sri S. Tjitrosoedirdjo, Dirga S. Pradana, Mei Linda Mardalena, Harry Imantho	B06	The development of database of plant specimen collected from core plots of EFForTS

Research summary

Starting in Phase 1 (2012) of EFForTS, B06 collected plant specimen (trees, shrubs, herbs) in the core plots of the project. The collected specimens were sent and processed into herbarium specimens at SEAMEO BIOTROP Herbarium (BIOT) Bogor. The process included mounting, labelling, identification, specimen picture capture, and transferring and compiling the data into an Excel file. Up to now, about 10,200 plant specimen have been collected and identified. Herbarium specimen were deposited in different herbaria in Indonesia (Herbarium Bogoriense (BO), Herbarium UNJA, SEAMEO BIOTROP Herbarium (BIOT), and in Germany (Göttingen University Herbarium (GOET). These specimens are voucher specimen that are used by the students and researchers. They contribute to a better understanding of the flora of Jambi, Sumatra.
The objectives of the study was to develop a database to collate and organize the information on the flora of Jambi, and to make it available to students, researchers and the public.

The database was created by MySQl program, using the Excel file of the collected specimen (Fig. 48). The Excel file contains data on the herbarium specimens including families, genera, species, photos of the herbarium specimens, location, collectors, date of the collection or information where duplicates have been sent to (Fig. 49).

No2	Coll numb	Coll. Name	duplicate	sheet	Herbarium	Species	Family	Genus
1	AW0001	Arne Wenzel			UNJA	*Nephrolepis acutifolia*	Nephrolepidaceae	Nephrolepis
2	AW0006	Arne Wenzel			BIOT	*Drynaria quercifolia*	Polypodiaceae	Drynaria
3	AW0007	Arne Wenzel			BIOT	*Drynaria quercifolia*	Polypodiaceae	Drynaria
4	AW0008	Arne Wenzel			BIOT	*Pyrrosia piloselloides*	Polypodiaceae	Pyrrosia
5	AW0009	Arne Wenzel			UNJA	*Pyrrosia lanceolata*	Polypodiaceae	Pyrrosia
6	AW0010	Arne Wenzel			BIOT	*Drynaria quercifolia*	Polypodiaceae	Drynaria
7	AW0011	Arne Wenzel			UNJA	*Asplenium nidus*	Aspleniaceae	Asplenium
8	AW0012	Arne Wenzel			GOET	*Asplenium nidus*	Aspleniaceae	Asplenium
9	AW0013	Arne Wenzel			GOET	*Vittaria ensiformis*	Vittariaceae	Vittaria
10	AW0014	Arne Wenzel			BO	*Davallia denticulata*	Davalliaceae	Davallia
11	AW0015	Arne Wenzel			BIOT	*Dendrobium leonis*	Orchidaceae	Dendrobium
12	AW0016	Arne Wenzel			BIOT	*Pyrrosia longifolia*	Polypodiaceae	Pyrrosia
13	AW0017	Arne Wenzel			UNJA	*Drynaria quercifolia*	Polypodiaceae	Drynaria
14	AW0022	Arne Wenzel			BO	*Monogramma sp.*	Vittariaceae	Monogramma
15	AW0025	Arne Wenzel			BIOT	*Pyrrosia lanceolata*	Polypodiaceae	Pyrrosia
16	AW0026	Arne Wenzel			GOET	*Pyrrosia lanceolata*	Polypodiaceae	Pyrrosia
17	AW0029	Arne Wenzel			BO	*Vittaria elongata*	Vittariaceae	Vittaria
18	AW0030	Arne Wenzel			BO	*Thelasis sp. 1*	Orchidaceae	Thelasis
19	AW0031	Arne Wenzel			UNJA	*Acriopsis liliifolia*	Orchidaceae	Acriopsis
20	AW0032	Arne Wenzel			UNJA	*Polypodiaceae sp. 1*	Polypodiaceae	Polypodia
21	AW0033	Arne Wenzel			UNJA	*Vittaria ensiformis*	Vittariaceae	Vittaria
22	AW0035	Arne Wenzel			BIOT	*Microsorum punctatum*	Polypodiaceae	Microsorum
23	AW0036	Arne Wenzel			BIOT	*Asplenium nidus*	Aspleniaceae	Asplenium
24	AW0039	Arne Wenzel			UNJA	*Phymatosorus scolopendria*	Polypodiaceae	Phymatosorus

Figure 48. Excel file containing data of the herbarium specimens.

During the development of the database, the website of SEAMEO BIOTROP was used temporarily and will be transferred to the CRC 990-EFForTS website.
The prototype was tested by numerous researchers from Göttingen, Biotrop and MSIB (Magang dan Studi Independen Bersertifikat, Kementerian Pendidikan, Kebudayaan, Riset dan Teknologi Indonesia). A user Manual has been developed. The final database will be included in the Darwin core (*https://dwc.tdwg.org*) and GBIF (Global Biodiversity Information Facility). Further ideas are to include the herbarium specimen from Biotrop as well into the database.
Suggestion for improvement of the database are: 1). Photo specimens should be completed for all numbers of the specimens, 2) some special terms are not familiar for the layman or users, it is necessary to include equivalent general terms, 3) the symbol for the location of the specimen on the distribution map is not clearly visible, 4) addition of an interactive feature on the map menu for more specific species, genera,

and families will be helpful and more interesting, and 5) specimen collected by Indonesian collectors could be added to the database.

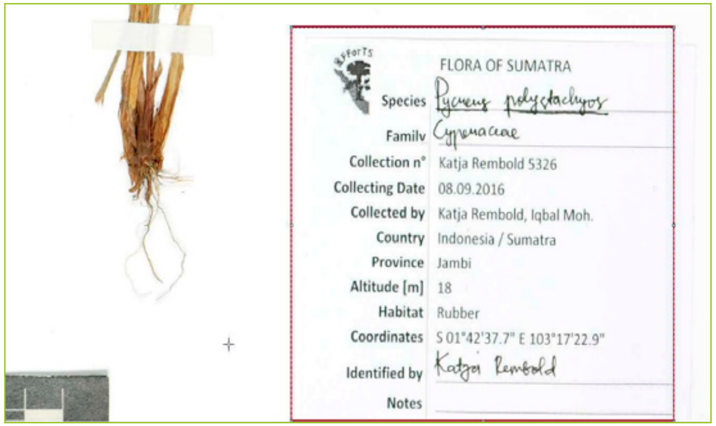

Figure 49. An example of the specimen image after opening by paintbrush.

Figure 50. The results of enlarging the photo.

Yeni A. Mulyani, Tri Ananda Nur Ikhsan, Azru Azhar, Gusthi Ayu Permatasari, Rizky Nazarreta, Windra Priawandiputra, Damayanti Buchori	**B09**	Evaluating biodiversity and ecosystem services in the Biodiversity Enrichment Experiment (BEE)

Research summary

Massive rainforest transformation into cash crop plantations has resulted in the loss of critical habitat for many plants and animals of the forests. Maintaining biodiversity with agroforestry that combines crop production with trees is one way to overcome the transformation impacts. Integrating between maintaining crop production and planting various trees has been proposed as a strategy to satisfy livelihood needs while increasing biodiversity and ecological functions. EFForTS established a large-scale and long-term biodiversity enrichment experiment using six different tree species planted in oil palm plantation sites, bird and insects survey in experimental enrichment oil palm plantation are very important to be studied. By investigating their diversity and functional role over time in the enrichment experimental in oil palm plantations, we could understand the influence of plant composition structure changing in a large monoculture plantation. A bird survey was previously conducted a year after the enrichment plots were established and based on our present result, the number of bird species remained relatively the same (20–21 species) but with changes in bird species composition, and the tree enrichment had a positive effect on bird and invertebrate communities. Insect biodiversity monitoring also has been conducted in 2018 and 2019 which indicated that enriched oil palm plantations using native tree species could enhance parasitoid and ants species richness. Tree enrichment had a positive impact on bird and invertebrate communities, however little is known about the effect of enrichment experiments on the ecological function provided by birds and insects. This study aimed to assess the effect of native tree enrichment on bird and insect parasitoid diversity in oil palm plantations, and also the plant-herbivore-carnivore interaction in the EFForTS-BEE research plot.

Bird surveys were conducted in the 20 x 20 m^2 (13 plots) and 40 x 40 m^2 (12 plots) sizes. Point counts with a radius of 50 m were used to bird survey from 6.00 to 10.00 am and, when necessary from 15.30 to 17.30 pm. Birds detected outside the radius of point count were also recorded but are not included in the calculation of bird diversity. Insect samplings were conducted using direct observation and traps. Lepidopteran larvae as herbivore representatives were collected and then observed daily. The lepidopteran larvae were observed daily to be recorded their development stages, parasitization rate, and the emerged parasitoid adult. A generalized linear mixed model has been used to analyze the parasitization rate Various plant diversity levels were set as a fixed factor and different plot sizes as a random factor in this experimental design.

A total of 33 bird species of 20 families were observed during the study, but only 24 species of 13 families were observed within the point count radius with total records of 345 birds (144 records in 20 x 20 m, and 201 records in 40 x 40 m). The most abundant species was Yellow-vented Bulbul (Pycnonotus goiavier). There were one protected species outside the radius of point count, i.e., the Changeable Hawk-eagle (Nisaetus cirrhatus).

Bird diversity was slightly higher in the larger enrichment plots (H' = 2.649; E = 0.845; Dmg = 4.418) than in smaller plots (H' = 2.291; E = 0.826; Dmg = 3.018). Based on its guilds, insectivores was the most dominant guild (48.5% of total species, 44.6% of total records), followed by frugivores (18.2% of total species, 28.5% of total records).

The study showed that larger plots of enrichment planting harbored higher species richness and diversity. As in other studies, oil palm plantation feeding guilds are dominated by insectivores. The bird species richness has increased in BEE plots by 57 % after 9 years of planting compared to the baseline data and one year after planting, suggesting that the enrichment plants had a positive impact on bird diversity in oil palm plantations. A similar result was found in the parasitization rate on herbivore insects, the parasitization rate was higher in the higher number of tree enrichment diversity (Fig. 51). Plant species enrichment on oil palm plantation significantly affect the parasitization rate of parasitoid to herbivore (glmer: X^2= 8.58; p= 0.035). This finding strengthened previous results in the same experimental plot that

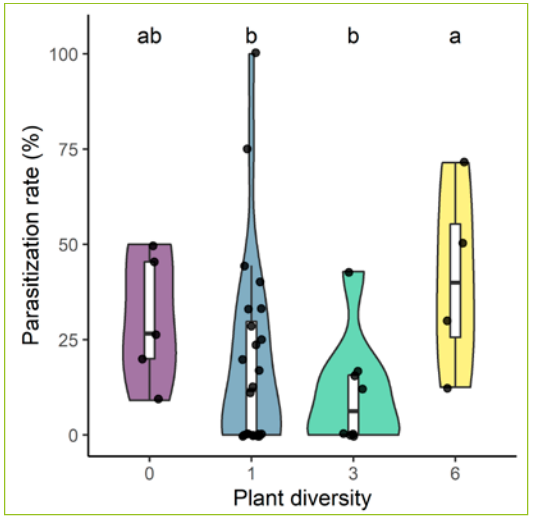

Figure 51. Parasitization rate in various plant diversity levels at Biodiversity Enrichment Experimental (BEE) plot at oil palm plantation. Different letters showed significant differences on Tukey HSD α = 0.05.

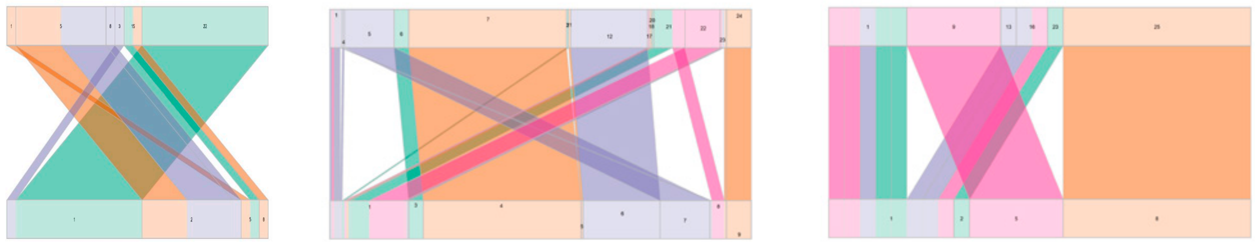

Figure 52. Interaction between parasitoid (upper column) and herbivore (bottom column) in various plants species diversity enrichments in oil palm plantation.

Different colors represent plot sizes: light green is 5x5 m^2, orange is 10x10 m^2, light blue is 20x20 m^2, and light magenta is 40x40 m^2. The upper columns indicate parasitoid species names and bottom columns indicate host species or family names.
Parasitoid: (1) *Triraphis* sp.01, (2) *Triraphis* sp.02, (3) *Triraphis* sp.05, (4) Triraphis sp.06, (5) *Trichogramma* sp.01, (6) *Carcelia falenarta*, (7) *Pediobius* sp01, (8) Hymenoptera sp01, (9) *Ceraphron* sp01, (10) *Trichogramma* sp02, (11) Chalcididae sp01, (12) Bethylidae sp03, (13) *Canaligoras* sp.01, (14) *Coccophagus gurneyi*, (15) Chalcidinae sp.01, (16) *Beyarslania* sp.01, (17) *Ceratosolen* sp.01, (18) *Apanteles* sp.01, (19) Exoristinae sp.02, (20) *Microplitis bomiensis*, (21) Bethylidae sp.01, (22) Eulophidae sp.01, (23) Hymenoptera sp.02, (24) Bethylidae sp.02, (25) Eulophidae sp.02.
Host: (1) *Erebidae* spp, (2) Limacodidae, (3) *Calliteara horsefieldii*, (4) *Mahasena corbetti*, (5) Noctuidae, (6) Crambidae, (7) Nymphalidae, (8) Geometridae, (9) Tortricidae, (10) *Calliteara* sp.

parasitoid diversity increased in line with the increasing plant diversity enrichment. Biodiversity enrichment using the native tree in oil palm plantations may also increase the parasitoid-host interaction complexity (Fig. 52). Several frequent pest species that mostly reduced oil palm production, such as nettle caterpillar (Lepidoptera: Eribidae), slug caterpillar (Lepidoptera: Limacodidae), and bagworms (Lepidoptera: Psychidae) were found parasitized by parasitoid insect in the experimental plots. These results indicated the enrichment of the oil palm plantation gave benefits in providing ecosystem services, either provided by birds or insects.

Iskandar Z. Siregar, Sri Rahayu, Ulfah Juniarti Siregar, Essy Harnelly, Fifi Gus Dwiyanti, Bambang Irawan, Muhammad Majiidu	**B14**	Genetic diversity of sungkai (*Peronema canescens* Jack.) and jengkol (*Archidendron pauciflorum* Benth.) in EFForTS-BEE assessed by microsatellite markers

Research summary

The success of ecosystem restoration through a variety of planting activities can be affected by several factors, one of which is the seed origin. The genetic diversity of seeds needs to be examined which is crucial to determine the success rate of the plantation. Jalonen *et al.* (2017) suggested that about 40% of reproductive materials of forest plants originated from fragmented populations with unwarranted quality. Therefore, high-quality Jengkol seedlings and Sungkai clones are needed with an adequate genetic base to increase the success rate of ecosystem restoration. The study has planted the seedlings (Jengkol) and clones (Sungkai) in Bogor and maintenance is being carried out regularly. On the other hand, microsatellite loci for both species were identified from the previous year, but the diversity analysis has not been conducted yet based on the representative number of samples. It is always desired that capacity to perform genetic analysis locally is available in Indonesia. The current CRC 990 project still uses mainly Sanger DNA Sequencer (ABI) for DNA analysis. Good handling (management and operation) of such a machine in Göttingen is an important experience and lesson to be learned and transferred to Indonesia since IPB has the machine located in the Advanced Research Laboratory (*https://advancedlab.ipb.ac.id/en/equipment/genetic-analyzer-abi-3500*). However, due to a lack of trained technicians, the utilization of the machine is not yet optimally performed. This project aimed to improve the capacity for conducting analysis of the genetic diversity of Jengkol and Sungkai originating from EFForTS-BEE experimental plots using microsatellite markers generated using ABI sequencing machine. In addition, it was aimed to train one technician from IPB to get familiar with the "tip and tricks" in handling the ABI sequencing machine (i. e., consumables, management, and operation)

A technician from IPB was trained in Göttingen for one month, while also conducting the microsatellite analysis for 20 singles tree progenies of Sungkai and 20 singles clonal ramets of Jengkol. Preparation for the training was conducted through virtual meetings as necessary before the technician is going to Germany.

Picture 28. Jengkol progeny trial in Forest Areas with Special Purposes, Parung Panjang, Bogor.

Picture 29. Sungkai clonal trial in Forest Park, IPB Dramaga Campus.

Maintenance of seedlings and clones was done in the progeny trial (Jengkol) located in Parung Panjang and the clonal trial (Sungkai) in IPB Darmaga campus. The growth performance of the two species is presented in Pictures 28 and 29. Vegetative and generative materials of Jengkol and Sungkai were collected from Biodiversity Enrichment Experiment (BEE) plots, PT Humusindo, Jambi.
Currently, the trials are being monitored to determine their growth and survival. In addition, the trials are also used as a showcase of using planting stocks from BEE-EFForTS plots.

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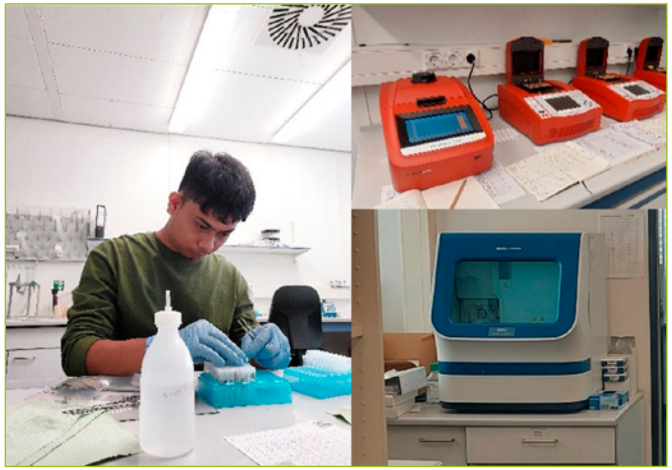


Picture 30. One of IPB junior staff went to the University of Göttingen to conduct training on handling the ABI sequencing machine from the 21st of September to the 6th of October 2022. During the training, the IPB staff did a microsatellite analysis using Jengkol and Sungkai species from Biodiversity Enrichment Experiment plots (BEE-EFForTS). Five primer candidates from previous work were used to analyze microsatellites for each species. The results showed that only one of five primer candidates works for SSR analysis of Jengkol. On the other hand, five primer candidates worked well for SSR analysis of Sungkai. During the training, the IPB staff also had the experience to join the Future PhD for Future Forest (F4) Symposium at the Faculty of Genetics and Tree Breeding, University of Göttingen.

Picture 31. Future PhD for Future Forest (F4) Symposium in Büsgenweg 2, 28-30 September 2022

Ulfah J Siregar	**B14**	Increasing sequencing coverage in Petai and Sungkai using ONT technology

Research summary

Chloroplasts are photosynthetic organelles that have small, conservative genomes and semi-independent behavior toward the nuclear genome (Kim *et al.* 2005). Because of its size and conservatism, the chloroplast genome has been frequently utilized to study plant origin and evolution. Five tree species, namely Petai (*Parkia scpeciosa*) and Jengkol (*Archidendron pauciflorum*) which belong to Fabaceae, Sungkai (*Peronema canescens*) of Lamiaceae, Jelutung rawa (*Dyera polyphylla*) and Jelutung darat (*Dyera costulata*) of Apocynaceae were planted to enrich and improve the biodiversity in the oil palm plantation in Jambi Province. Although all those species are well known as favorite community trees and seemed able to grow well anywhere in Indonesia, recent observations in the field showed that not all species could adapt and grow well in the experiment. The objective of this research is to increase sequencing coverage in Petai (*Parkia speciosa*) and Sungkai (*Peronema canescens*) as the main species and three other species using Oxford Nanopore Technology (ONT).

Materials were leaves collected from the same trees used for short-read and long-read sequencing in the previous study. DNA samples were extracted using CTAB method (Cetyl Trimethyl Ammonium Bromide) with modification. The quantity of extracted DNA are measured using Qubit 1.0 Fluorometer Invitrogen (Qubit dsDNA BR) and quality was assessed using NanoPhotometer NP80 Implen. The usable DNA sample must have A260/A280 quality in the range of 1,7 – 2,0. Long-reads sequencing was done using MinION device connected to the computer of Intel Core i7,16 GB RAM, 1 TB hard drive, and operating system using Linux Mint 19.2, according to manufacture protocols SQK-NBD112.24 from Nanopore with the used flowcell type R.10.4.1. Sequencing result with Fast5 format then stored dan converted to Fastq format for further bioinformatics analysis, such as base calling.
Raw sequences data from a previous study (short-reads and long-reads) and new raw data (long-reads) with fastq format were assembled through the following process based on the pipeline from *https://github.com/asdcid/Chloroplast-genome-as-*

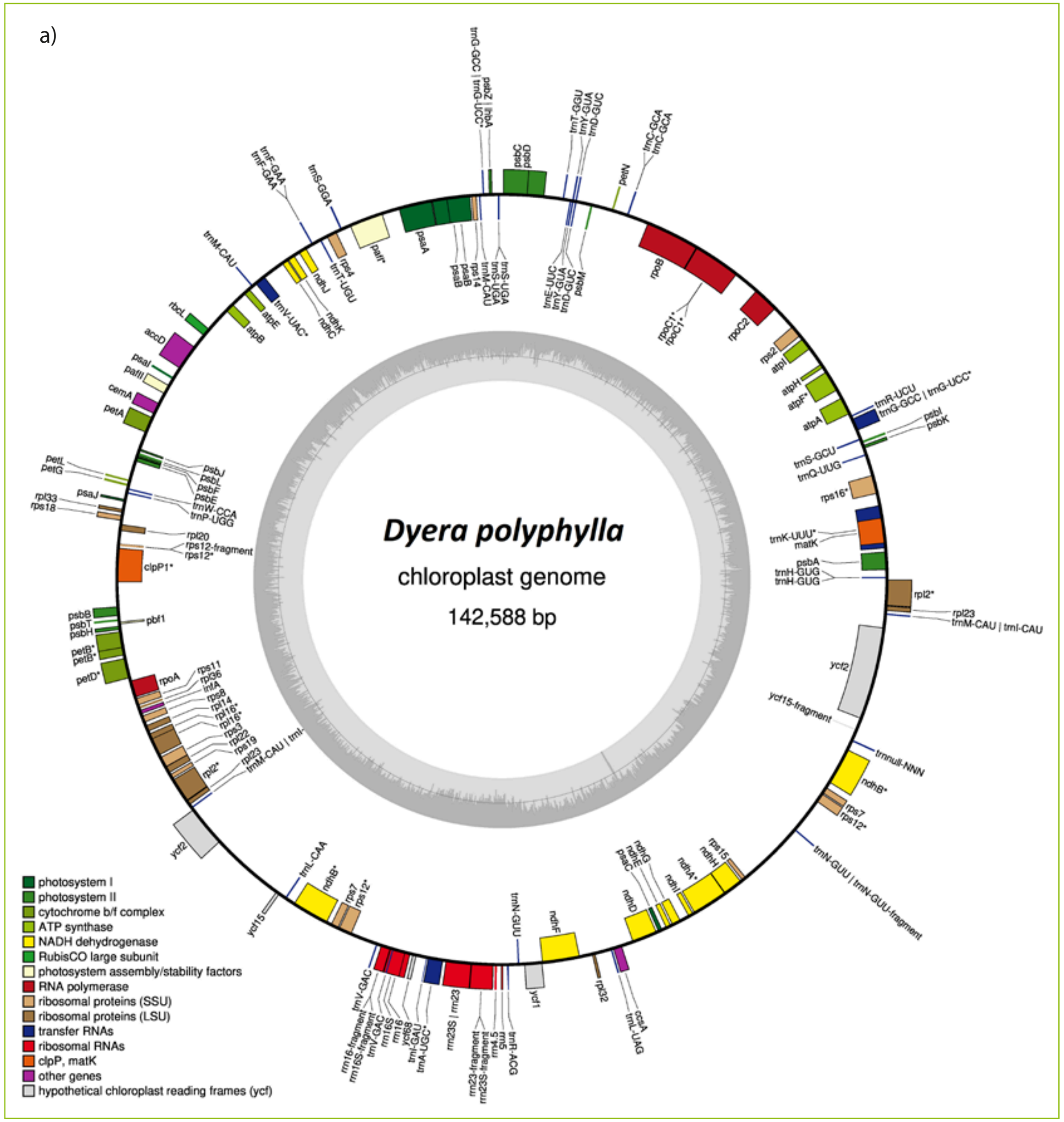
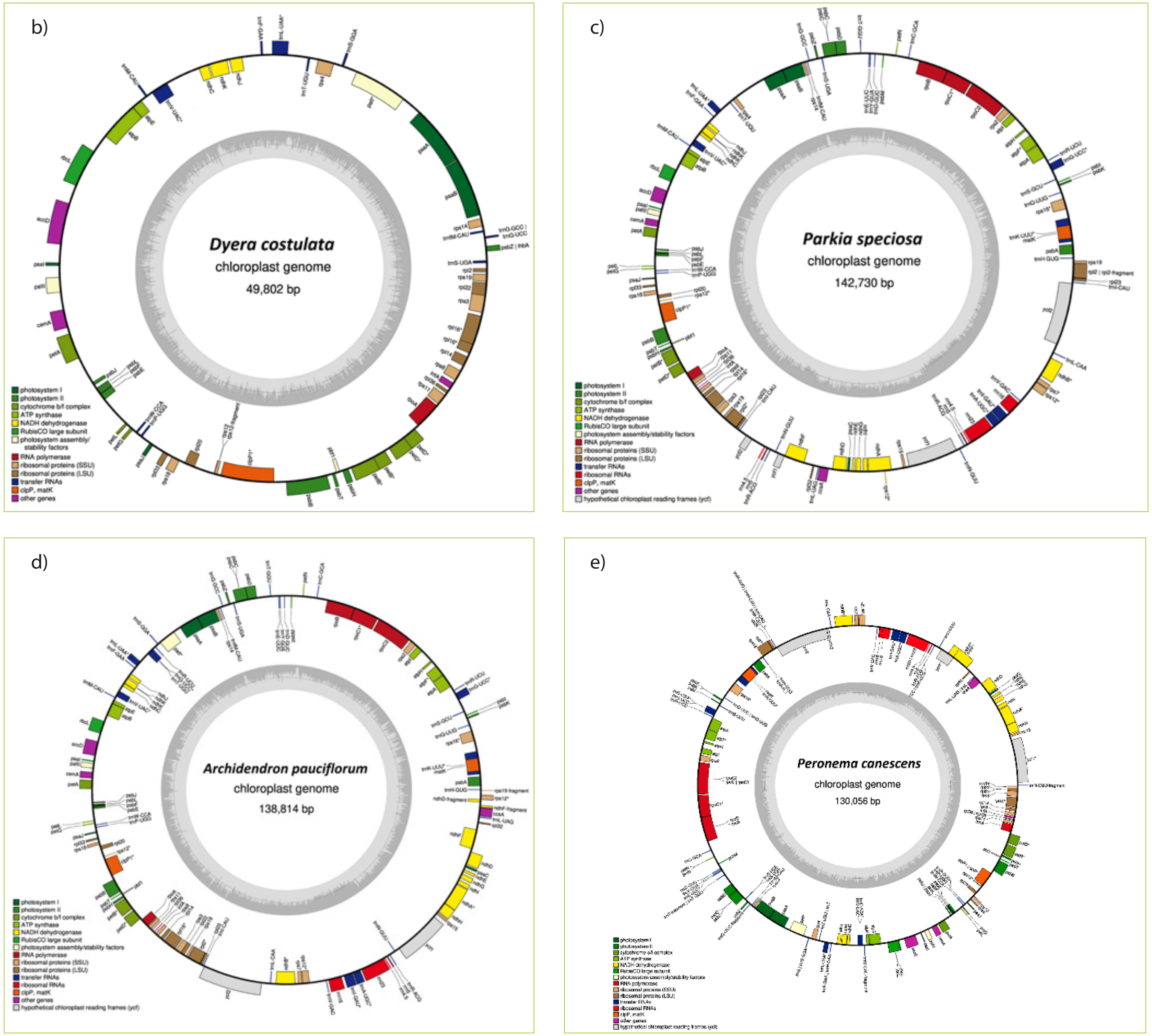


Figure 53a-e. Circular map of Chloroplast genome **(a)** *D. polyphylla*; **(b)** *D. costulata*; **(c)** *P. speciosa*; **(d)** *A. pauciflorum*; **(e)** *P. canescens*.

sembly. For gene annotation, we used GeSeq (Tillich *et al.* 2017) under MPI-MP Chlorobox to annotate the assembly result. For the annotation reference, we use all chloroplast genome references of each family and visualized them using OGDraw. Phylogenetic analysis was constructed using MEGAX using a maximum likelihood algorithm with 1000 bootstrap values.

All the data from both previous and current experiments was used to assembly the chloroplast genome of Jengkol (*A. pauciflorum*) and Petai (*P. speciosa*) of (Fabaceae), Jelutung rawa (*D. polyphylla*) and jelutung darat (*D. costulata*) of (Apocynaceae), also Sungkai (*P. canescens*) of Lamiaceae as presented in Figure 53.



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Dodik Ridho Nurrochmat	**Z01**	Reconciling conflict of interest in the management of forest restoration ecosystem: A strategy to incorporate different interests of stakeholders in the utilization of the Harapan Rainforest, Jambi, Indonesia

Background and Objectives

This study analyzes the interests and influences of all stakeholders involved in utilizing the Harapan Rainforest. It aims to identify the stakeholders involved and provide a policy recommendation for the contestation in the Harapan Rainforest. The stakeholder analysis method is used to analyze and categorize stakeholders' interests and influences in the Harapan Rainforest utilization, promoted by Reed *et al.* (2009). This research provides an alternative conflict resolution strategy in the context of smallholder oil palm plantations within forest areas in Indonesia

The methodology used by the study is the stakeholder analysis, stakeholder analysis is a tool that can be used in the negotiation or learning process among stakeholders in solving common problems.
The initial step of this study was to identify the stakeholders involved in utilizing the Harapan Rainforest. We then categorized the stakeholders, using the interest-influence matrix, referring to Reed *et al.* (2009). Finally, the results of the previous steps were used as a consideration for building a strategy to incorporate the different interests of stakeholders.

This study found that there are three common interests in the Harapan Rainforest. Firstly, stakeholders have an interest in conserving and protecting forests. Secondly, stakeholders are interested in utilizing forest land for oil palm cultivation to generate income. Lastly, the third stakeholders are interested in forest policy and environmental justice enforcement. This study found eight stakeholders involved in the Harapan Rainforest
There are three main local community groups (LCM) in the Harapan Rainforest: the Migrant Group, the Batin Sembilan Group, and the Malay Group. Each group consists of several farmer groups and is characteristically utilizing the Harapan Rainforest (Rahmani *et al.* 2021). Almost all Harapan Rainforest local communities have a high dependency on the forest. However, most of them utilize the Harapan Rainforest forestland for oil palm cultivation. Migrant and Malay groups utilize forestland to cultivate oil palm and a small amount of rubber. They sell oil palm fresh fruit bunches and rubber to Toke/middleman (TKE). Meanwhile, most Batin Sembilan people collect NTPFs, but after realizing the success of migrant people who planted oil palms within the Harapan Rainforest, they also planted oil palms. PT REKI assists the Batin Sembilan people to cultivate rubber, so they do not expand their oil palm in Harapan Rainforest.

Each stakeholders then divided into 2 measuring power level (high and low) with three different criteria, based on the influence to the restoration, and resulted in the table below:

Table 5.

No	Stakeholders	Power Category
1.	PT Restorasi Ekosistem Indonesia (REKI)	Legitimate
2.	Local community (LCM)	Reward
3.	Middleman/*Toke* (TKE)	Reward, referent
4.	PT Berkat Sawit Utama (BSU)	Legitimate
5.	Yayasan CAPPA Keadilan Ekologi (CAPPA)	Referent
6.	The Collaborative Research Center 990 (CRC)	Expert
7.	The Forestry Service of Jambi Province (DKJ)	Coercive, legitimate
8	Production Forest Management Center Reg. IV (BPHP)	Coercive, legitimate

This study identifies stakeholders' interrelation, using the social network analysis (SNA) approach. Figure 54 shows the stakeholders' network in the utilization of the Harapan Rainforest. Blue nodes are *context setters*, red nodes are *key players*, yellow nodes are *subjects*, and green nodes are *crowds*. Different line thicknesses indicate differences in the closeness of the relationship among stakeholders.

This study found that REKI is the central stakeholder of the network because it has the biggest out-degree and in-degree value. REKI has the power to spread information to other stakeholders in the network. REKI also has relationships with important stakeholders (BPHP, DKJ, and CAPPA) in the network, because they have the biggest eigenvector value. PT REKI also becomes a "bridge" that plays as an intermediary role in connecting various stakeholders in the network of Harapan Rainforest contestation. Based on this result, REKI can connect with other stakeholders. It can be a privilege to lead better management in Harapan Rainforest. PT REKI has a good connection with BPHP and DKJ as the local government institutions with power in the policy-making of Harapan Rainforest management. PT REKI can partner with CRC to provide innovations in sustainable forest management that can harmonize forest rehabilitation and oil palm production. PT REKI also can also partner with CAPPA to encourage the local community to prevent or even stop the expansion of oil palm cultivation within the Harapan Rainforest.

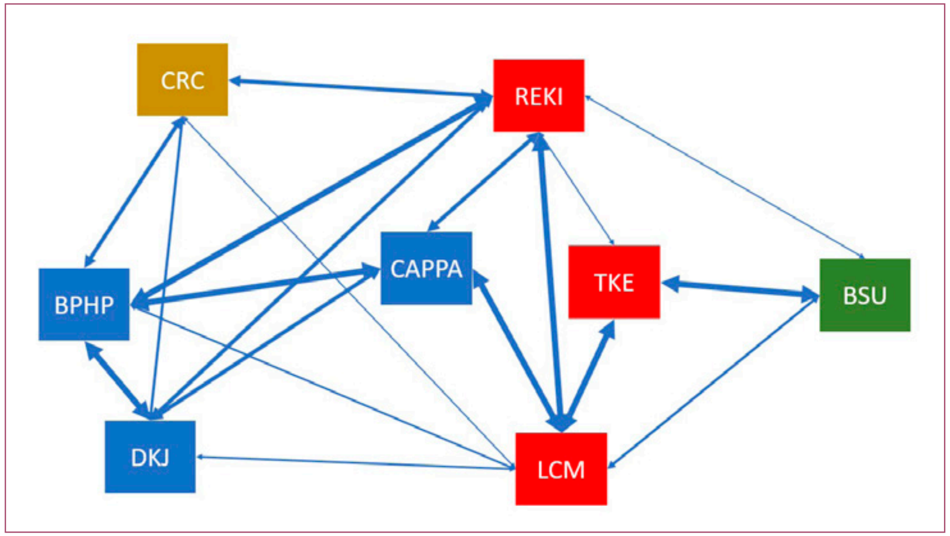

Figure 54. Stakeholders' network in the utilization of Harapan Rainforest.

As the remaining lowland rainforest in Sumatra, Indonesia, the Harapan Rainforest provides much ecological and economic benefit, specifically to local stakeholders. Nevertheless, the Harapan Rainforest ecosystem has been threatened, due to the different and even contradictory interests of its stakeholders. This study found three stakeholders are the key players who have direct roles in the Harapan Rainforest utilization. In contrast, the other five stakeholders play indirect roles. One of the biggest threats to the Harapan Rainforest ecosystem is the local community's conversion of the forest into oil palm. Strict law enforcement is one option for addressing this threat. But, given the complexity of forest ecosystem restoration problems in the Harapan Rainforest, influenced by socio-culture and economic factors, successful implementation is improbable. Therefore, it is necessary to provide a proper strategy as a win-win solution to reconcile different interests and encourage cooperation among stakeholders.

This study proposes a policy strategy promoting oil palm agroforestry to reconcile ecological and economic interests in the Harapan Rainforest. To implement this strategy, it is important to build common ground between PT REKI (REKI), the local community (LCM), and the *toke*/middleman (TKE) toward the oil palm agroforestry program as a win-win solution in the Harapan Rainforest. It is also important to consolidate the management plan with The Forestry Service of Jambi Province (DKJ) and Production Forest Management Center Reg. IV (BPHP) as a local government organization. CAPPA can assist the local community to ensure the successful implementation of oil palm agroforestry.

According to the findings of this study, there is a potential avenue for further research in the future. Research into intercrops' suitability toward climate and soil conditions in the Harapan Rainforest is important to ensure that oil palm agroforestry is possible to implement.

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Damayanti Buchori	**Z02**	Developing an insect database through citizen science using *iNaturalist* as a mapping tool

Research summary

iNaturalist is a free access networking platform for scientists, biologists, and nature enthusiasts to share about worldwide biodiversity mapping. Observations from iNaturalist can also contribute to biodiversity science by being shared with open science projects such as the Global Biodiversity Information Facility (GBIF) and the Encyclopedia of Life (EOL), accessed through a smartphone or a website. iNaturalist contributors are worldwide public, not exclusively for researchers and experts. Therefore, this platform may create extensive community awareness of local biodiversity and promote further exploration of the local environment which could be accessed by people in other parts of the world. This platform also could provide young researchers and citizen scientists who are interested in entomology to study, document, and contribute to insect data mapping in Jambi, in the EFForTS study plots in particular.

Moreover, insect diversity surveys are very important since they showed a declining population which suppressing by Anthropocene. We already documented several groups of insects, such as ants (Nazarreta *et al.*, 2021), butterflies (Panjaitan *et al.*, 2021), beetles (Kasmiatun *et al.*, 2022), spiders (Junggebaeuer *et al.*, 2021), and wasps (Azhar *et al.*, 2022) in book references. Synchronization between books and *iNaturalist* platform would provide a novelty in describing the distribution of beneficial insects in a digital platform that is easy to access from any place and device. Although iNaturalist has many benefits, there is still a lack of Indonesian researchers who optimize this platform. We would like to bridge the problem by providing iNaturalist workshops including general training and field work to young researchers, entomologists, and students who are interested. These kinds of activities are expected to create future generations who have an awareness of local biodiversity and participate in worldwide biodiversity conservation actions. The name of this training is '**E-Capture** (**E**FForTS-**C**onserving and M**ap**ping of Biodiversity in Nat**ure**): Exploring Nature using iNaturalist'.

The aim of this activity is to give general training and workshop about iNaturalist and further develop the citizen science movement for insect biodiversity conservation through training on the identification of important insect predators and pollinators (i.e. ants, bees, butterflies, dragonflies) and training on iNaturalist platform (field sampling, identification, and develop database). In addition, to develop citizen science movement on insect biodiversity conservation. As a result, participants will be able to use the iNaturalist app to map observations and document various species in Jambi. By optimizing the platform, we will have the newest and most updated digital maps of pollinator and predator insects in Indonesia.

This training was held over two days, with details as follows:

1. Training at EFForTS study plot

This training was held at one of the EFForTS plots in Humusindo, Bungku. A total of 21 EFForTS assistants participated in this training. The training began with a presentation about the introduction of *iNaturalist* by Naufal Urfi Dhiya'ulhaq. All participants were also taught to create an iNaturalist account. Then, the training continued with a practical section in the field to collect various documentation of plants and insects in this plot. Furthermore, the results were uploaded to iNaturalist along with the species name and the coordinates of the location where they took the picture.

2. Training at the University of Jambi

The training began with a short course from two speakers, i.e. Dr. Jochen Drescher (who talked about insects and the results of EFForTS-Z02 research in Jambi), and Naufal Urfi Dhiya'ulhaq (who talked about the introduction of *iNaturalist* app). This course was moderated by Dr. Purnama Hidayat from IPB University. After this, all participants moved to UNJA forest to collect insect specimens and take pictures of the species they found. Then they went back to the room (Aula Hakim Lubis) to upload all the documented species to iNaturalist. Small species have been observed under a microscope before being documented. About 30 participants from various backgrounds, including UNJA students, lecturers, EFForTS assistants, and the general public, attended this training.

Picture 32. E-capture workshop at umusindo.

Picture 33a+b. E-capture workshop at UNJA.

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Purnama Hidayat	**Z02**	Canopy spiders and bees of Jambi Province: A photographic field guide

Research summary

Arthropods are the most numerous and diverse group of animals. Tropical rainforests are important habitats that ensure the existence of a wide variety of arthropods. Spiders belong to a large category of animals called Arthropoda, which all have an outer exoskeleton that covers their segmented bodies and jointed legs. This canopy spiders field guide addresses the spider fauna of rainforest canopies in Jambi Province, Sumatra – Indonesia, and closes a critical gap in the literature. Up to now, there was no guide to one of the most diverse but understudied tropical spider communities that comprise many new species and genera that await discovery and scientific description. Since the rainforests of Sumatra are under immense anthropogenic pressure, it is safe to assume that many species might be lost before they can be documented. These specimens that we have in Z02 group belong to 445 morphospecies in 95 genera and 36 families which is a very high number for such a specialized habitat and the size of the area. This guide provides a baseline for monitoring the largely undescribed spider community of the lowlands of Sumatra, especially regarding jungle rubber, rubber, and oil palm.

Bees are part of pollinating insects that provide important ecosystem services in the pollination process. Bees are in the order Hymenoptera and superfamily Apoidea (James & PittsSinger, 2008). They have erect and plumose hair on their bodies. An estimated about 20.000 to 30.000 species of bees have been described worldwide (Michener, 2007), however little is found on information about bee species and their distribution in Jambi, Sumatra, Indonesia. A Field Guide to the Bees of Jambi Province provides a detailed introduction to the estimated 63 species of Sumatran bees, Jambi particularly. This book is designed to introduce the bees in Jambi, including their description, distribution, and identifying features. Illustrated with stunning photographs, it describes the form and function of bees and also contains systematic accounts of the five families. We hope that this book will help amateur naturalists, entomologists, and bees enthusiast in the effort of bee identification and further may support bee diversity restoration and conservation.

Within the framework of the EFForTS project, we collected bees using insect nets and traps, and spiders from the canopy in a nested design in four land-use systems in Jambi Province, Sumatra. Studies on bees and spiders' diversity and responses to land use change in forest areas are still limited, so more research is needed on a regular basis to document photographs. Based on this study, we made two field guides for spiders (Spiders of Jambi: A photo guide to the EFForTS collection) and bees (An Illustrated Guide to 62 Types of Bees in Jambi, Sumatra). All of those guides are a collection of the results of collaborative research through the EFForTS project and focused as a guide that can provide information about the important value of photography and illustration of spider and bee diversity.

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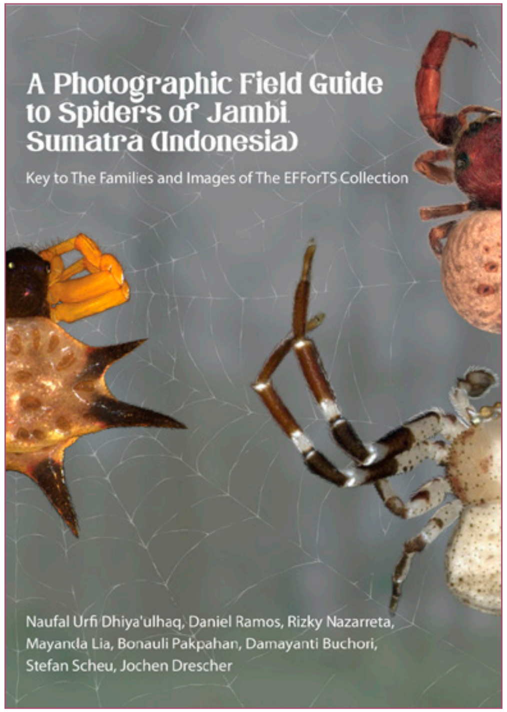

Picture 34. Cover of "A Photographic Field Guide to Spiders of Jambi Sumatra (Indonesia)".

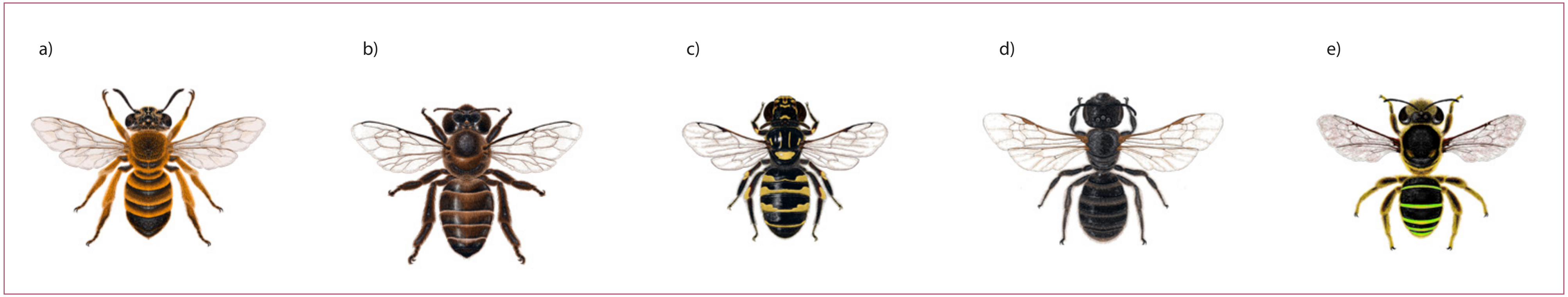

Figure 55. Selection of illustrated bees in Jambi: **a)** Amegilla insularis, **b)** Apis cerana, **c)** Ceratina liftiencky, **d)** Halictus sp, **e)** Nomia strigata.

Research projects of counterparts funded at UNJA

Name	Counterpart	Title
Damris Muhammad, Nurzeni Fitri	**A05**	Assessing farmer management practices and greenhouse gas emission of smallholder oil palm plantations in Jambi province

Research summary

At the COP-26 Summit in Glasgow in 2021, Indonesia set an ambitious greenhouse gas (GHG) reduction target of net zero emissions by 2060. To achieve that goal, all sectors that contribute to the national GHG emissions have to take the necessary action to lower the GHG emissions. Agriculture is one of the contributing sectors to GHG emissions (Glenday and Paoli, 2015). It is estimated that more than 300 million tons of soil carbon have been lost from forest transformation to oil palm plantations (Shanmugam *et al.*, 2018). Indonesia is the world's major CPO producer, with a total oil palm area of more than 16 million ha, and is the biggest contributor to non-CO_2 emissions to the atmosphere. Indonesia, therefore, needs to take systematic action for the reduction of GHG emissions from the agricultural sector to support Indonesia's net zero emission by 2060.

National and international climate policies are more concentrated on reducing GHG emissions in the energy, industry, and transportation sectors and deforestation (Smith *et al.*, 2008). However, there is a lack of focus on the potential to reduce GHG emissions from agriculture. Agriculture activities contribute about 17% to GHG emissions and 7–14% to land use change (OECD, 2015). Agriculture in tropical developing countries is estimated to account for 7–9% of anthropogenic GHG emissions annually (Smith *et al.* 2014). Jambi Province is one of the ten highest-priority provinces in Indonesia to be considered for improvements to policies and programs related to smallholder oil palm farmers' improving management practices to achieve improved yield as well as to climate change (Woittiez *et al.*, 2021). The study aimed to identify smallholder farmer management practices contributing to GHG emissions from oil palm plantations.

This study was conducted in Muaro Jambi, Jambi Province. Data were collected from June to September 2022. Smallholder oil palm farmers owning 2 hectares or less of oil palm cultivation were chosen as respondents. Fifty smallholder farmers were interviewed to identify the farmers' activities in managing oil palm cultivation. The respondent scores were then grouped into the following categories: (1) 0-25% is categorized as bad (highly contributes to GHG emissions), (II) 25.01-50% (moderately contributes to GHG emissions), (III) 50.01-75% (lowly contributes to GHG emissions), and 75.01-100% is categorized as no contribution (no contribution to GHG emissions).

The 50 respondents represented a diversity of oil palm ages and farmer demographics. The farmers managed an average of 1.8 ha. The majority of farmers were aged between 40 and 53, and female respondents were in the minority (14%). In this study, the farmer's activities related to emission production are limited to agriculture, land use, forestry, tree cutting, and burning activities. Emissions practices include cutting trees for firewood, burning bushes for weeding, burning bushes as part of land clearing activities, and burning bushes after cultivation. Figure 1 shows the number of farmers' activities participating in production emissions based on these four categories.

It can be seen from Figure 56 that the farmers are participating in all four activities that are contributing to the emissions. Of the total 50 farmers participating in this study, all are involved in activities contributing to emission production, such as cutting trees for firewood (92%), burning bushes for a wedding (86%), burning bushes for land clearance (72%), and burning bushes for cultivation (96%). The majority of farmers weeding by burning bushes, clearing land after cultivation and gathering wood for cooking, which may be related to the smallholders' large contribution to emissions (Israel MA *et al.*, 2020). On average, 86.5% are engaged in activities that produce emissions.

The high contributions of smallholder farmers toward GHG emissions compared to farmers that implement Smart-Climate Agriculture (SCA) may indicate that the farmer's awareness and knowledge of the emissions from management practices are important factors for emission reduction. Advocacy for CSA adoption could be a necessary condition for environmental protection through the reduction of GHG emissions (Israel MA *et al.*, 2020).

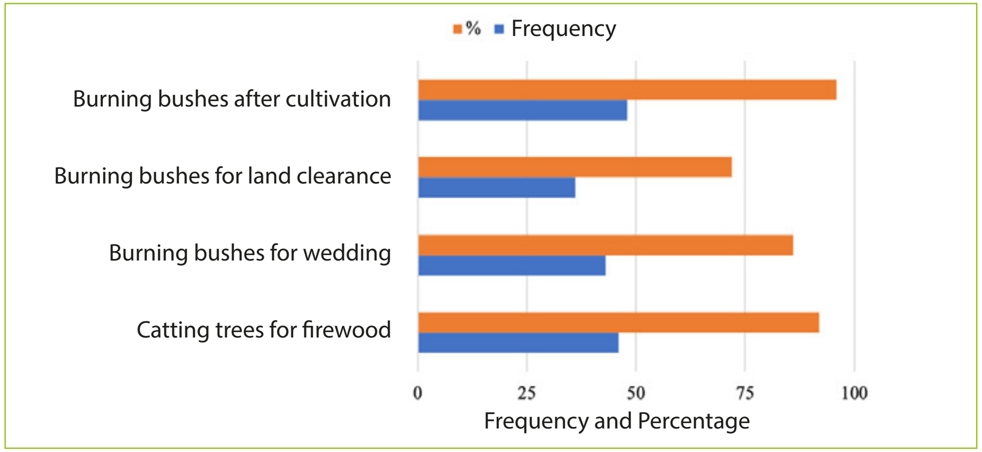

Figure 56. Farmers' activities contributing to emission production.

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Revis Asra, Joko Ridho Witono, Izu Andry Fijridiyanto, Upik Yelianti	**B14**	Genetic diversity of Jernang (*Calamus* spp.) in Sumatra, using ISSR markers

Jernang rattan (Dragon's Blood Palm) belong to the Arecaceae family, which was previously included in the genus *Daemonorops*. Based on molecular and morphological phylogenetic evidence, this genus was transferred to the genus *Calamus* (Baker, 2015). There are more than 400 species of calamus (Baker, 2015), but only 12 species produce red resin. In Sumatra, five species of Jernang (*Calamus acehensis*, *C. brachystachys*, *C. draco*, *C. dracuncula*, and *C. dransfieldii*) have been found (Rustiami *et al.* 2004).
The red resin has a high economic value and is used as a natural dye and medicine (diarrhea, anti-tumor, anti-viral, anti-microbial, and bleeding. The population and production of Jernang decreased strongly (BKSDA Jambi 2010) due to illicit logging and the conversion of forests into oil palm and rubber plantationn (Sulasmi *et al.*, 2012a; Sulasmi *et al.*, 2012b). To support the conservation and cultivation of this Jernang species, it is necessary to know the genetic diversity of this plant. Molecular techniques are commonly used for the analysis of genetic diversity within and between populations. One of the molecular markers that can be used that has a high level of polymorphism is efficient, and inexpensive is the Inter Simple Sequence Repeat (ISSR) marker. ISSR is the most widely used marker to study clonal diversity and population genetic structure (Rossetto *et al.*, 1999).
The objective of this study was to examine the genetic diversity of four Jernang species in Sumatra by using ISSR markers in order to assess the extent of genetic variation and to discuss the conservation implications based on the genetic characteristics as conservation recommendations for those species.

Leaf samples of 10–25 individuals of four Jernang species in Sumatra (*Calamus Confusus*, *C. Longipes*, *C. Draco* and *C. Melanochaetes*) from Sarolangun Regency, Jambi Province (Sepintun, Lamban Sigatal, and Taman Bandung) and Aceh Utara Regency, Aceh Province (Riseh Teungoh Village, Sawang District) were collected and stored in silica gel prior to extraction.

All genomic DNA was extracted from silica gel-dried leaf tissues. DNA was isolated using the Quick-DNATM plant/seed MiniPrep Kit (Zymo Research) according to the manufacturer's manual. DNA samples from each plant were analyzed individually to detect intra- and inter-population variations as well as sex determination markers.

The DNA amplification was carried out following ISSR techniques. An initial screening of 20 ISSR primers that were successfully utilized in other plant species (Sarmah *et al.*, 2017; Asra *et al.*, 2014; Sarmah & Sarma, 2011; Younis *et al.*, 2008) was performed in order to test their readability and amplification profiles for polymorphism. Fourteen to fifteen markers were selected and used in this study for each Jernang species.

The amplified DNA fragments generated by ISSR markers will be processed using the electrophoresis with 5 µL of the standard DNA and a 1 kb DNA ladder (100 ng µL-1) in the first slot of 1.5% agarose gel in TBE 1X as the buffer solution. Then, the agarose gel was run using electrophoresis technique at 100 volts for 60 minutes at room temperature. The resulting amplified bands were observed and documented using the Gel Doc™ EZ Gel Documentation System (Bio-Rad). Each reaction was repeated at least twice to get reproducible bands.

DNA bands derived from PCR amplification of each sample at a marker locus were considered one allele. DNA bands that have the same migration rate were assumed to be homologous loci in the sample. The ISSR bands were scored as binary data, in which the presence and absence of bands in a given size class were converted to 1 and 0, respectively. The genetic relationships of each Jernang species were evaluated based on similarity coefficients as implemented in the NTSYS-PC software version 2.1 (Rohlf, 2000). Heterozygosity index (H), polymorphism information content (PIC), discriminating power (D), effective multiplex ratio (E), marker index (MI), arithmetic mean heterozygosity (Havp), and resolving power (R) were conducted using the iMEC software program online (Amiryousefi *et al.*, 2018).

Seven species of Jernang from Sumatra were collected in this study: Jernang Aceh (*Calamus confusus* (Furtado) W.J.Baker), Jernang Kalumuai (*Calamus longipes* Griff.), Jernang Rambai (*Calamus draco* Willd.), Jernang Umbut (*Calamus melanochaetes* (Blume) Miq.), Jernang Burung (*Calamus gracilipes* Miq.), Jernang Kelukup (*Calamus* sp.), and Jernang Landak (*Calamus* sp.). However, the three species (Jernang Burung, Jernang Kelukup, and Jernang Landak) were collected from fewer than five individuals, so these three species were excluded from the analysis. The other four Jernang (Jernang Aceh with 20 accessions, Jernang Kalumuai with 17 accessions, Jernang Rambai, and Jernang Umbut with 25 accessions and 10 accessions, respectively). In this study, selected 14 primers (Jernang Aceh, Jernang Rambai, and Jernang Umbut) and 15 primers (Jernang Kalamuai) used for genetic diversity analysis and relationship analysis of each Jernang species produced amplification products (scorable bands) and all resulted in polymorphic fingerprint patterns.

The lowest and highest polymorphism indices of four Jernang species from Sumatra. The heterozygosity index (H) ranged from 0.3200 (Jernang Umbut) to 0.5000 (Jernang Rambai). The polymorphism information content (PIC) of the primer ranged from 0.3209 (Jernang Kalamuai) to 0.4134 (Jernang Rambai). The effective multiplex ratio (E) ranged from 3.240 (Jernang Rambai) to 9.500 (Jernang Aceh and Jernang Umbut). The arithmetic means heterozygosity (Havp) ranged from 0.0011 (Jernang Kalamuai) to 0.0058 (Jernang Umbut). The marker index (MI) ranged from 0.0049 (Jernang Rambai) to 0.0296 (Jernang Umbut). The discriminating power (D) of the primer ranged from 0.3615 (Jernang Umbut) to 0.9438 (Jernang Kalamuai). The resolving power (R) of the primers varied from 1.2 (Jernang Umbut) to 12.5 (Jernang Kalamuai). The PIC values of all Jernang species showed that values higher than 0.25 and lower than 0.5 were included in the moderate category (Botstein *et al.*, 1980).

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Mirawati Yanita, Gina Fauzia (Jambi University)	**C01**	The Positive outcomes of ISPO certification towards the sustainable management practices of palm oil of smallholders in Jambi Province

Research summary

The palm oil commodity business contributes to increased agricultural and employment incomes and reduced poverty (Byerlee, 2017; Qaim *et al.*, 2020). Smallholders benefit from palm oil cultivation by raising household living standards (Kubitza *et al.*, 2018). Indonesia is the world leader both in production and land area. The rapid expansion of oil palm plantation areas has substantial socio-economic implications (Euler *et al.*, 2017). The stage of development for oil palm plantations has shifted. Smallholders have dominated the ownership of oil palm plantations, especially in Jambi Province. While the number of oil palm smallholders who adopted ISPO certification is 1,006.92 hectares or only 16 percent in Jambi Province. ISPO certification is expected to be carried out consistently with good management practice implementation for the oil palm business.

The objective of the research is to describe the characteristics of independent oil palm smallholders who hold ISPO certifications based on good agricultural practices through social and economic analysis of problems based on the actual conditions.

The data analysis methods used in this study are qualitative descriptive analysis and quantitative analysis. The first objective was to analyze descriptively by collecting data related to the profiles of independent smallholders certified for social, economic, and ecological attributes. In comparison, the second objective was a problem based on the actual condition of independent oil palm farmers based on agricultural farming activities based on *Good Agricultural Practices (GAP) and Best Management Practices (BMP)* represented by the principles and criteria for independent schemes and farmers.

Table 6. Outcomes in implementation of the production input

No	Input description	Smallholders	Norm
1	Farm size (ha/farmer)	2,9	-
2	Fertilizer		
	-Urea	305,9	204
	-NPK	317,9	340
	-KCL	304,8	272
	-TSP	317,9	306
	-Dolomite	111,3	272
	-Organic fertilizer	285,4	0
	Fertilizer used (kg/ha/year)	1649	1.394
3	Pesticide (liter/ha/year)	7,8	10
4	Labour		
	-Family Labour	0,2	-
	-Non-Family Labour	0,8	-
	Labour Amount (Working Labour day/ha/year)	1,0	-
5	Agriculture tools	11	-
6	Production (ton/ha/year)	26,7	27
7	Price (IDR/kg)	1.994	2.010

Based on a study of 75 ISPO farmers in the study area, the farmers' age was ranging from 25 to 74 years old. The age of farmers who adopted ISPO in the interval group of 49-56 years old was 25.33%, and the second largest was in the interval 41-48 years old at 21.33%. The level of farmer education varies from elementary to bachelor's degrees. Smallholders who obtained education at the elementary level had a higher rate of 54.67 %. The number of their family members ranges from 2 to 5 person. Smallholders who have a minimum of three members in their family had a larger percentage, it is 37.33 %. According to Anim (2011), the number of family members or labor providers in cultivation activities. Smallholders who have 11 to 13.9 years of farming experiences were the largest group, 31% respectively. On the other hand, the ISPO certification, it took place since 2018 only. Farmers have farm size from 1.93 to 3.15 hectares, was 57.33%. The average farm size of oil palm in this study was 2.9 hectares. Smallholders who reached 17.71 to 22.21 ton per ha of yield per year are 39.67%.

The value and acceptance of ISPO as a sustainability standard are expected to increase over time. However, the implementation of ISPO in the field has not shown significant incentives for smallholders. Some main challenges in implementing ISPO certification include land tenure status, traceability, farmer inclusivity, transparency, and the certification mechanism. To overcome these obstacles, several options to improve are needed, such as streamlining licensing procedures with improved governance, enhancing the capacity of independent farmers, developing the capacity and institutions of independent farmers through training, establishing regular extension services, providing access to funding, and ensuring price stability at market.

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Rosyani, Fuad Mukhlis, Fazriyas, Neliyati, Nurhikmah	C02	Factors that affect the implementation of oil palm replanting in Jambi Province, Sumatra

Research summary

Oil palm smallholders in Jambi province are currently facing difficult times with declining production. This is due to the age factor of the oil palm trees, as the plantations have exceeded their economic lifespan, yet a significant portion of the land that should have been replanted remains untouched. This study's objective was to determine the condition of the oil palm replanting process and to analyze the factors that potentially influence farmers' decisions to implement the replanting of oil palm.

Jambi province has nine districts that have a distinct number of oil palm smallholders (Fig. 57). Our samples were taken from three districts, namely Tanjung Jabung Barat, Muara Jambi, and Merangin. In these three districts, there are farmers who have conducted replanting and those who have not yet. The sample consists of 298 farmers located in the district with the largest oil palm plantation area and the largest area of old plantations. Each district was chosen using the simple random sampling method (Department of Forestry and Plantations,

Table 7. Result of Analysis

Variable	B	wald	sig	Exp (B)
Land area (X1)	1,758	5,326	,021	1,248
Famers acceptance (X2)	4,816	3,888	,027	123,481
Another source of income (X3)	3,732	3,931	,047	,024
Price of TBS (FFB) (X4)	,331	7,748	,005	,970
Subsidies from the government (X5)	,471	,458	,499	,624
Involvement in a farmer association (X6)	6,222	5,492	,222	,000

2021). The analysis method used in this research is binary logistic regression. The analysis tool used in this research is logistic regression, shown by Nasir, 2014; Bungin & Burhan, 2013; and Sugiono, 2018.

Y = 1 ; if the farmer decides to replant the oil palm
Y = 0 ; if the farmer decides not to replant the oil palm
The initial model of the binary logistic regression equation formula can be seen as follows:
$Pi=E(Yi=1|Xi)=\beta_0+\beta iXi$

Farmers are expected to be able to explain the process of replanting that they undertake, starting from the initial implementation of replanting to the end process. Furthermore, the results of the data analysis explain factors such as land area owned by farmers, their income, other sources of income, the price of Fresh Fruit Bunches (FFB), government subsidies, and involvement in farmer groups. Those factors affect the success of the implementation of replanting. The involvement of smallholders in a farmer association is identified as the dominant factor to replant their oil palms. This means that oil palm farmers should be part of an active farmer association to accelerate the replanting process (Table 7).

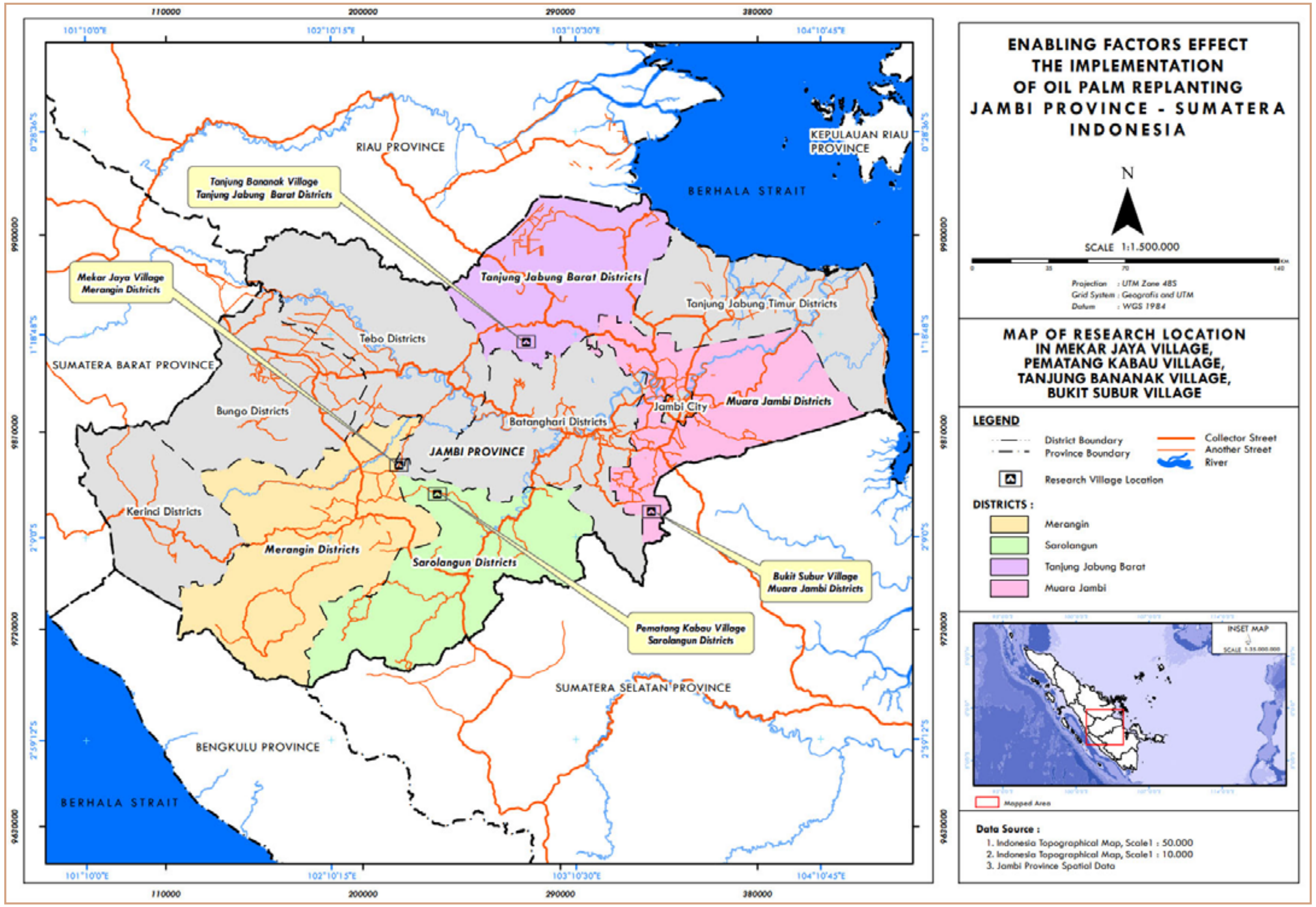

Figure 57. Research location

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Ummi Kalsum, Zulkifli Alamsyah	C07	Health status of female oil palm farmers and feeding pattern of children related to malnutrition (stunting) in under five-year-old children of smallholder households in Muaro Jambi Regency, Jambi Province

Research summary

Jambi Province has more than 1,000 hectares of oil palm plantations and ranks 6th in Indonesia in terms of acreage. In Jambi province, Muaro Jambi has the largest oil palm plantations, it has grown very rapidly in the last ten years. The expansion of oil palm plantations has a major impact on the environment, flora, fauna, and socio-economic changes such as the level of family welfare, including health. Oil palm plantations are usually located far from the city center, which means access to health services is quite difficult. Changes in women's work from the domestic sector to the public sector, as plantation workers, have an impact on women's health and nutritional status, also causing changes in feeding practices. This results in nutritional deficiencies such as being underweight, having chronic energy deficiency (CED), anemia for women, and malnutrition (stunting) in children. Disruption to the health status of the mother is associated with an increased risk of stunting in her under-five children. Stunting is a condition of failure to grow and develop in children due to a lack of nutritional intake for a long time, so children are shorter than their age. Stunting is still a serious public health problem in Indonesia and Jambi Province. The prevalence of stunting in Muaro Jambi regency experienced a significant increase from 13.5% in 2019 (the lowest among 11 regencies/cities) to 27.2% (the highest) in 2021. The impact of stunting is disruption of brain development, physical growth, intelligence, and metabolic disorders in the body. While the long-term impact is getting sick easily, the emergence of diabetes, heart and blood vessel disease, obesity, cancer, stroke, disability in old age, and poor quality of work contribute to low productivity. There are many causes of stunting, which come from various factors, from children, mothers, and families to environmental health conditions. Food intake and infectious diseases; feeding practices and food diversity; food security; sanitation; and the root of the problem is poverty (family socioeconomic level). Many program policies have been carried out for the handling and prevention of stunting, as well as convergence in accelerating the reduction and prevention of stunting nationally, but have not succeeded in reducing the prevalence of stunting to < 20% in under five-year-old children. The role of women as mothers for the health of themselves and their families, especially their toddlers, is very important.

This study aimed to analyze the relationship between maternal nutritional status, maternal health, and feeding practices for toddlers and the incidence of stunting in oil palm farmer households in Muaro Jambi Regency, Jambi Province.

The research method was a cross-sectional study. Mothers and toddlers from 227 oil palm farmer households from 8 villages have been randomly selected with the dominant community working as oil palm farmers in Muaro Jambi regency. The villages selected (Sungai Dayo, Mulya Jaya, Sumber Jaya Bahar Utara, Sumber Jaya, Tarikan, Ladang Panjang, Parit, and Tanjung Katung) were also research locations of subproject C07 of EFForTS. Data collection was conducted through interviews and anthropometric measurements (height, weight, and mid-upper circumference). The independent variables were maternal nutritional status (body mass index and chronic energy deficiency), morbidity (health status of the mother), and feeding patterns. The dependent variable was stunting, which was measured using height/age < -2 standard deviation. Data analysis used multiple logistic regression at 95% confidence intervals.
The prevalence of stunting in toddlers was 30.4%. The nutritional status of the mother was 4,8% underweight, but overweight was 48,9%, and CED was 8.4%. Poor feeding patterns reached 38.3%. The morbidity of mothers with infectious diseases was 10.1% (data not shown).
Factors related to stunting incidence were maternal nutritional status (underweight, overweight, or obese mothers), chronic energy deficiency, and poor feeding patterns. The dominant factor of stunting in toddlers of oil palm farming families was the CED of mothers, after being controlled by the nutritional status of mothers and feeding patterns. CED mothers have a 2.15 times greater risk of their children suffering from stunting than mothers who are not CED (healthy) after being controlled by their nutritional status and feeding patterns (Table 8).

This final model proved to be significant, with an omnibus P-value of 0.013 and an overall percentage of 70%. It means that the model formed can predict the occurrence of stunting in toddlers by 70%, and the rest is explained by variables that have not been examined in this study.

Table 8. The final model of determinants of stunting in toddlers of oil palm farmer household in Muaro Jambi Regency, Jambi Province, Indonesia 2022

No.	Variables	B	*P-Value*	Prevalence Odds Ratio	95% CI
1.	Maternal nutritional status		0.052		
	Underweight	0.245	0.737	1.27	0.30–5.33
	Overweight to obesity	0.759	0.015	2.13	1.15–3.93
2.	Chronic Energy Deficiency	0.767	0.169	2.15	0.72–6.41
3.	Feeding patterns	0.467	0.123	1.59	0.88–2.89
	Constant	-1.732	0.140		

We conclude that the CED of mothers increases the risk for their children to suffer from stunting as well as being underweight, overweight, and having poor feeding patterns compared to mothers without CED (healthy mothers) in oil palm smallholder farmer households. It is recommended to apply a healthy lifestyle, eat a balanced and diverse nutritional diet for the mother, and give good attention to her feeding practices for her children. Improving nutrition and health education is very necessary for mothers.

Upik Yelianti, Evita Anggereini, Raissa Mataniari	**PR**	Development of a booklet with teaching materials for plant taxonomy courses about orchids in the Harapan Rainforest, Jambi

Research summary

Orchids are appreciated for their aesthetic appearance and have a high economic value in society. They are widespread and occur in many different habitats. However, natural orchids are becoming rare in Jambi Province due to the decrease of their habitat, e. g. devastating forest fires in 2015 and 2019 where many trees used by orchids have died or illegal logging.
The aim of this study was to document the presence of orchids in Jambi province in a booklet for teaching purposes in order to preserve the diversity of orchid species.

The development of the booklet is based on the ADDIE model with five stages, respectively: A (analyze), D (design), D (develop), I (implement), and E (evaluate) (Lee and Owens, 2004). This research begins with a needs analysis showing that the presence of natural orchid species in Jambi has begun to decrease due to the disturbance of its habitat. Therefore, it needs to be documented in the form of a booklet as a supplement to teaching materials so that this information can be disseminated, especially to students. At the design stage, activities are carried out to determine the schedule, and the initial design of the booklet media, and compile the product assessment instrument. Next, in the "develop" stage, activities are carried out: determining material from various reference sources, looking for orchids at the collector level to be photographed, then making booklets. In the implementation phase, trials were carried out on the booklet of orchids as a product of the trial subjects, namely students of the Biology Education Study Program at Jambi University.

Research on the development of research-based booklets on orchid materials in Jambi Province has been completed. The development of the media booklet resulted from documenting Jambi's natural orchids at the collector level by taking photographs. Then it is described and identified according to the literature, both books and journals.

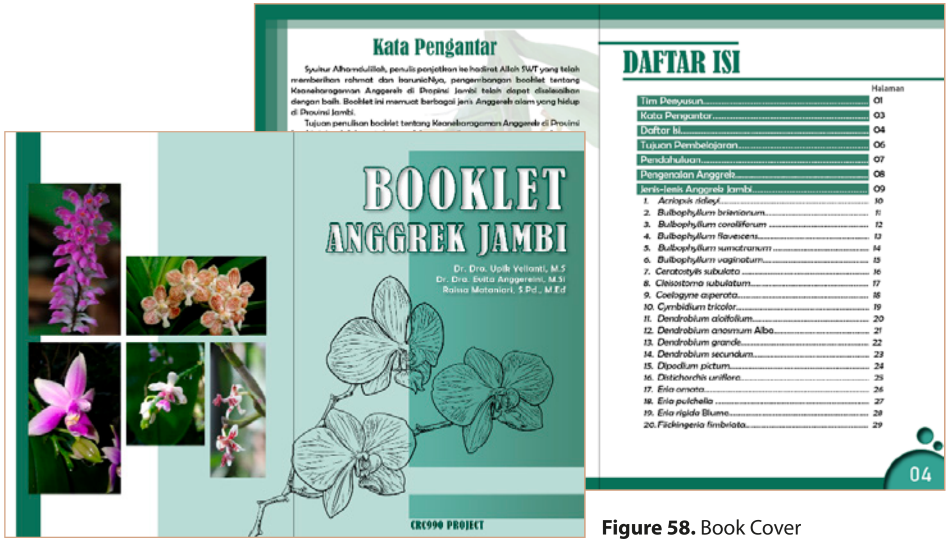

Figure 58. Book Cover

The results of the first stage of content expert validation of the developed booklet obtained a score of 36 (69.23%) in the good category. However, there is still revision needed, namely the addition of learning objectives. After being revised, the score increased to 43 (82.69%) in the very good category.
Based on the results of the first stage of validation, the orchid media booklet in the province of Jambi obtained a score of 36 (69.23%) with good criteria. Then revisions were made based on suggestions from material experts, so that in stage II validation, a score of 43 (82.69%) was obtained in the very good category. The revised sections are on learning objectives, basic competency content, and suitability of the material for basic competencies.
After the content expert declared the booklet valid, the learning media expert validated it. It obtained: 50 (62.50%) in the unfavorable category. Furthermore, the booklet was revised according to input from media experts and re-validated so that it obtained a score of 73 (91.25%), which is in the very good category.

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Research project of counterparts funded at Tadulako University

Name	Counterpart	Title
Henry Novero Barus, Nur Edy	**Z01**	DNA barcoding of arbuscular mycorrhizal fungi from Central Sulawesi

Research summary

Arbuscular mycorrhizal fungi (AMF) is a term to describe a mutualistic symbiotic relationship between plant roots and fungi. AMF supports the decomposition of soil organic materials, the translocation of soil nutrients, especially phosphorus, and the ability of plant roots to absorb plants and protecting roots from pathogens in the rhizosphere.
This study aims to identify arbuscular mycorrhizae at the species level by DNA barcoding and publish them on a data bank website. The results of this study will contribute to national biodiversity data on arbuscular mycorrhizae from Central Sulawesi.

Sampling was carried out in three different land uses in Central Sulawesi: monoculture cocoa plantations, cocoa agroforestry, and forest areas. Isolation of mycorrhizal spores using the pour filter method (Brundrett *et al.*, 1996), which has been modified according to INVAM (https://invam.ku.edu). DNA extraction and amplification by polymerase chain reaction (Edy *et al.*, 2022) were carried out at the Faculty of Agriculture, Tadulako University. DNA sequencing analysis is in process and will be carried out at IPB University.

In total, 25,502 spores from 21 different genera of AMF have been collected and identified (Table 9).

The species richness of a certain number of samples is based on the rarefaction curve. The rarefaction curve is a plot of the number of species against the number of samples. This curve is constructed by randomly resampling a set of N samples several times and then plotting the average number of species found

Table 9. The identified AMF from three different land uses; cocoa plantation, cocoa agroforestry, and forest.

No.	AMF genera	Cocoa plantation	Cocoa Agroforestry	Forest
1	*Acaulosporalaevis*	364	366	543
2	*Acausporalaevislike*	626	335	784
3	*Chetaspora*	57	441	558
4	*Claoroidelgomus*	393	1,741	388
5	*Racocetragregaria*	723	9,453	3,116
6	*Rhizopagus*	77	752	1,138
7	*Gigaspora* MT-1	5	72	106
8	*Gigaspora* MT-2	84	36	52
9	*Gigaspora* MT-3	-	9	15
10	*Funneliformis* MT-1	30	383	324
11	*Funneliformis* MT-2	-	74	24
12	*Funneliformis* MT-3	-	46	38
13	*Claoroidelgomuse*	-	51	118
14	*Diversisporagaea*	-	18	18
15	*Acaulospora* MT-1	-	2	3
16	*Acaulospora* MT-2	-	21	69
17	*Acaulospora* MT-3	-	-	4
18	*Dentiscutata*	230	44	140
19	*Sclerocystis*	1	2	39
20	*Rhizopagus*	-	2	176
21	*Racocetra*	-	3	1,408
	Total	2,590	13,851	9,061
	%	10.16	54.31	35.53

in each sample. Generally, it grows rapidly initially (as the most common species found) and then flattens slightly (as the rarest species remains in the sample). The rarefaction curve shows that forest areas have higher AMF richness than those found in cocoa agroforestry and cocoa plantations (Fig. 59).

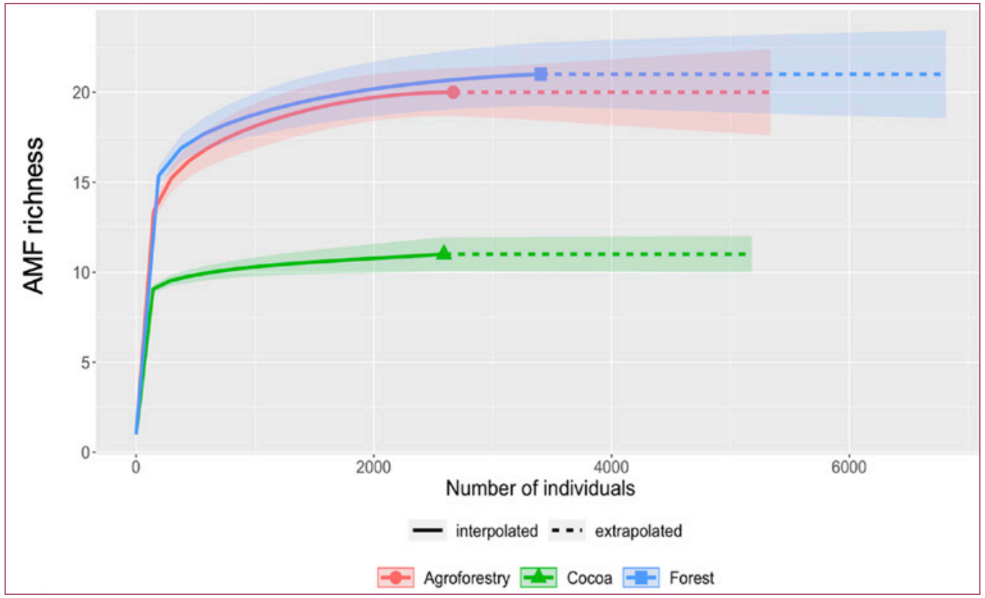

Figure 59. Rarefaction curves of arbuscular mycorrhizal richness in cocoa plantations (cocoa), cocoa agroforestry (agroforestry), and forest areas (forest)

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INVAM (2022) The International Collection of (Vesicular) Arbuscular Mycorrhizal Fungi

Research project of counterparts funded at Universitas Pendidikan Ganesha

Name	Counter-part	Title
I Nengah Suparta, Luh Mitha Priyanka, I Wayan Muderawan, Ketut Srie Marhaeni Julyasih, I Wayan Sukra Warpala, I Gede Arjana	PR	The development of SSI learning module related to CVPD disease in citrus plantations at Kintamani, Bangli, Bali

Research summary

CVPD (*Citrus Vein Phloem Degeneration*) is a widespread disease in citrus plantations in Kintamani, Bangli, Bali, affecting the production and lowering the income of farmers. Socio-scientific teaching and learning (SSI-TL) has been suggested as an effective approach for supporting meaningful learning in school contexts (Sadler *et al.*, 2017).
The research aims to prepare a SSI module based on CVPD disease infecting citrus plantation in Kintamani Bangli-Bali. Information on CVPD disease infecting citrus plantations in Kintamani Bangli-Bali will be collected and used as material for the creation of SSI-based learning modules that can be used as student learning tools using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model (Fig. 60).

Design Stage

Here, students will learn about CVPD as a disease that attacks citrus plantations. They will analyze the symptoms of CVPD in citrus (Pic. 35a, b). In the second section, this module will help students engage with three-dimensional learning related to CVPD disease, which attacks citrus plantations. They will discover disciplinary core ideas, crosscutting concepts, and scientific practice in these socio-scientific issues. After that, students will learn to find a possible way to prevent this disease in citrus plantations (including evaluation and reflection) through *Integrated Management of Healthy Citrus*. In the last section, the concept of sustainable development is introduced and it is discussed how far *Integrated Management of Healthy Citrus* relates to that. In every section, the module is completed with the learning objective, some information related to the issue, a summary, and an evaluation.

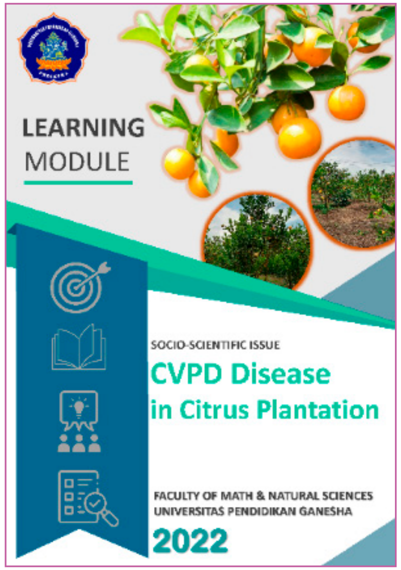

Figure 60. Cover design of this module using a citrus picture from the farm.

Apart from the information gotten from the interview with citrus farmers regarding the CVPD disease, the module will also cover some information related to the ways to preclude this CVPD disease by identifying the insect vector by analyzing DNA and citrus leaves. The identification started off by collecting samples from the leaves of citrus plants with symptoms of CVPD diseases. Observation of symptoms of CVPD (Citrus Vein Phloem Degeneratioan) disease is done visually. The results of visual observation of the typical symptoms of an attack on the leaves of citrus plants, in general, are indicated by chlorosis on the leaves, such as symptoms of deficiency of Zn and Mn elements. On the basis of visual observations, the signs of CVPD disease on Siamese citrus leaves in each location exhibited differing levels of chlorosis. When citrus plants are infected with CVPD, the leaves turn yellow or green, the leaf veins stay green, the size of the leaves shrinks, and the leaves become stiff.

Development Stage

Judges will review the module based on the design, content, and also language. This module (prototype 1) will be tested by two expert judges from the biology and chemistry education department. In the second evaluation, expert lecturers also give some feedback regarding the language and design of SSI module for

Picture 35a+b. Here, students will learn about CVPD as a disease that attacks citrus plantations. They will analyze the symptoms of CVPD in citrus.

better improvement. Finally, this module will be review by 15 selected students as they will use this module in next semester.

The results of prototype 2 evaluation by expert lecturers and selected students show that the SSI module developed is suitable for use and ready to implement next semester. By learning using contextual issues students will learn through experience instead of memorizing. Contextual learning can encourage students to have a more positive attitude toward learning science. When students can relate the concepts, they have learned to real-life situations, it means that they have inserted the context learned into the actual situation and transformed it into a life experience (Suryawati & Osman, 2017). The developed learning module will be based on contextual issues related to CVPD disease, which attacks several citrus plants and causes losses to local farmers. With the development of this learning module, students are expected to gain insight and understanding of CVPD issues, as well as raise awareness about some common issues in their surroundings and participate in environmental preservation.

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Sadler TD, Foulk JA, Friedrichsen PJ (2017) Evolution of a model for socio-scientific issue teaching and learning. International Journal of Education in Mathematics, Science and Technology 5: 75-87

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1B. RESEARCH PROJECTS OF COUNTERPARTS AND STAKEHOLDERS IN 2023

Proposed Researcher		Research activities
Rika Raffiudin, Nina Ratna Djuita, Windra Priawandiputra, Hidayatus Sholihah Tisniasari, Tiara Sayusti	A01	*Student research* Biology and melissopalynology of the honey bee *Apis Koschevnikovi* (Hymenoptera: Apidae) in Belitung
Tania June, Muhammad Syukron, Laila Kurniati P.	A07	*Student research* Water status of oil palm plantation as indicated by latent heat fluxes minus sensible heatfluxes and its relation to net ecosystem exchanges
Triadiati, Sri Sudarmiyati Tjitrosoedirdjo, Yohana C. Sulistyaningsih	B04	*Book/Atlas* Stem anatomy of trees in Harapan Rainforest, Jambi
Triadiati	B04	*Student research* a) Metabolomic analysis as a biomarker of oil palm tolerant to water availability b) Functional diversity in fine root traits of tropical transformation systems and belowground competition and resource partitioning in oil palm enrichment plantations
Yeni A. Mulyani, Damayanti Buchori, 2. Mirza D. Kusrini, 3. Rizky Nazarreta, 4. Bonauli Pakpahan	B09	*Books* A) Birds of Jambi: An illustrated field guide of the EFForTS collection B) An illustrated field guide of the amphibians and reptiles of Jambi
Sri Rahayu (BRIN)	B14	*Book* Hoya diversity in a changing habitat of Jambi, Sumatra, Indonesia
Sri Rahayu (BRIN) Iskandar Z. Siregar	B14	*Research* RU-HOYA : Information system of Indonesian Hoya diversity
Purnama Hidayat, Damayanti Buchori, Azru Azhar, Rizky Nazarreta	Z02	*Books* A) A guide of the canopy Braconidae of Jambi B) Establishing an illustrated insect identification key of EFForTS using LUCID Software
Damayanti Buchori, Purnama Hidayat, Sri Sudarmiyati, Yeni A. Mulyani, Rizky Nazarreta, Boanuli Pakpahan	Z02	*Batik Art-book* From science to art: Bridging research to community awareness through biocultural diversity

2 A. ABS – SCHOLARSHIPS FOR EARLY CAREER RESEARCHERS OF COUNTERPARTS & STAKEHOLDERS

In 2022 and 2023, EFForTS extended two scholarships and awarded twelve new ones.

Name of student	Affiliation Indonesia	Affiliation Göttingen	Title / Abstract	Funding period
Rahmi Ariani Doctoral researcher	Tania June, IPB University	Alexander Knohl – **A07**	*Modelling the effect of land use change on soil carbon dynamics in Indonesia*	Apr – Dec 2023 Final financing of the doctoral thesis
Winda Ika Susanti Postdoctoral researcher	Rahayu Widyastuti, IPB University	Stefan Scheu – **B09**	*Soil Fauna in the Lowland Rainforest and Agricultural Systems of Sumatra: Changes in Community Composition and Trophic Structure with Focus on Collembola*	Apr – Sep 2023
Patrick Diaz **& Ellena Yusti** Trainees	Windra Priawandiputra, IPB University & LIPI/BRIN	Catrin Westphal – **B09**	*Effects of tree island enrichment plantings in oil palm on colony development of stingless bees*	Jul – Oct 2023
PROJECT SUMMARY	From January to June 2023 two colonies of the common stingless bee species *Tetrangondula laeviceps* were placed in the center of 56 experimental tree islands within the EFForTS-BEE project in Jambi, Sumatra. Colony development and performance was continuously monitored during this time, by measuring colony size and colony activity monthly. In addition, inventories of flowering plants species within plots and regular pollen samples from inside the colonies, as well as from returning workers, were taken. Patrick and Ellena stayed in Göttingen for three months to 1) Clean and review the collected field data, 2) Select and prepare pollen samples for metabarcoding analysis, 3) Analyze the data of colony development in relation to the biodiversity enrichment experiment, 4) Prepare a paper for publication in a peer-reviewed international journal, and 5) Participate in trainings on statistical data analysis and data visualization.			
Yabes God Anugrah Panjaitan Bachelor student	Bambang Irawan, Jambi University and Iskandar Siregar, IPB University	Oliver Gailing – **B14**	*Genetic diversity of fragmented populations of ironwood (Eusideroxylon zwageri Teijsm. & Binn.) in Indonesia*	Jan – Apr 2023
PROJECT SUMMARY	The overall objective of this research was to study the genetic diversity in and between E. zwageri fragmented populations. Specifically, the objectives are: 1) To estimate the genetic diversity level within and among fragmented populations, and 2) To determine the genetic differentiation and genetic partition within and among islands. Samples were collected from three main islands where E. zwageri can be found naturally, namely Sumatera, Belitung and Kalimantan. 410 samples had been collected from 14 populations. Seven population samples were collected from Sumatra, 2 populations from Belitung and 5 populations from Kalimantan. New samples will be collected from 6 populations namely (1) KHDTK Kemampo, Banyuasin in South Sumatera, (2) Bukit Peramon (Belitung), (3) Eastern part of Jambi Province (Muaro Jambi and Tanjung Jabung Timur District, (4) KHDTK Kintap (South Kalimantan), (5) Sumber Barito Sub District, Murung Raya, Central Kalimantan, (6) The natural arboretum managed by PT Suka Jaya Makmur on Nanga Tayap Sub District, Ketapang, West Kalimantan. The samples were analyzed in the Genetic Laboratory of the Forestry Faculty, IPB University and in the Laboratory of Forest Genetics at the University of Göttingen.			

Immanuel Manurung Doctoral researcher	Leti Sundawati, IPB University	Meike Wollni – **C08**	*Community-led sustainability transformation in oil palm dominated landscapes – A Participatory Action Research approach in Jambi Province, Indonesia*	Oct 2022 – Dec 2023
PROJECT SUMMARY	The overall aim of this project is to explore and implement transformation pathways towards more sustainable land-use value and chain management in two villages in Jambi Province. This transformation strives to enhance local biodiversity and ecosystem functions while at the same time creating and safeguarding economically interesting and socially acceptable livelihood options, thereby contributing to an increase of the multi-functionality of landscapes. Applying a Participatory Action Research (PAR) approach, the researcher will facilitate and at the same time analyze a community-led process of a long-term sustainable transformation in an iterative framework of planning, action, and reflection. Combining qualitative and quantitative data analysis in a mixed-method approach, the researcher will investigate, how co-generation of knowledge and community-led planning processes can engage oil palm smallholders and related stakeholders to initiate sustainable transitions on a village level, how their capacity can be strengthened for developing an inclusive transformation agenda, and which outcomes and impacts for ecological, economic and social sustainability evolve through this process. The focus areas for transformation will encompass the diversification and enrichment of agricultural production systems, particularly in oil palm plantations, and the diversification of related agriculture value chains.			
Amanda Mawan Doctoral researcher	Damayanti Buchori, IPB University	Stefan Scheu & Jochen Drescher – **Z02**	*Diversity, Phylogeny and Trophic Ecology of Arboreal Collembola Communities along a Lowland Rainforest Transformation Gradient*	Feb 2022 – Jun 2023 Final financing of the doctoral thesis
Azru Azhar Doctoral researcher	Purnama Hidayat, IPB University	Stefan Scheu & Jochen Drescher – **Z02**	*Inter-annual dynamics of diversity and trophic ecology of Braconid wasp communities along a lowland rainforest transformation gradient*	Dec 2022 – Dec 2023
PROJECT SUMMARY	The proposed research aims at revealing the effects of rainforest conversion to rubber and oil palm plantations on a group of ecologically and agriculturally important natural enemies of herbivore pests, i.e. the parasitoid wasps of the family Braconidae. The proposed PhD research will be carried out in three work packages (WPs), that are planned to be published in international journals as three separate papers: WP1 – Changes in the diversity and phylogeny of Braconid wasps with changes in land use, WP2 – Spatial and temporal dynamics of Braconid wasp communities in a land-use change scenario, and WP3 – Ecological niche plasticity of arboreal Braconid wasps in response to land-use change.			
Naufal Rizqulloh Doctoral researcher	Damayanti Buchori, IPB University	Stefan Scheu – & Jochen Drescher – **Z02**	*Diversity, Phylogeny and Trophic Ecology of Arboreal and Terrestrial Ant Communities along a Lowland Rainforest Transformation Gradient for*	Feb – Dec 2023
PROJECT SUMMARY	The proposed research aims at revealing the effects of rainforest conversion to rubber and oil palm plantations on arboreal ants (Formicidae), an arthropod group so essential to the structure and functioning of tropical terrestrial ecosystems that they are termed "ecosystem engineers". The research project will be carried out in three thematic work packages (WP): WP1 – The taxonomic diversity of canopy and litter ant assemblages across different land-use systems at the landscape level, WP2 – The molecular phylogeny of canopy and litter ant assemblages using DNA barcoding, and WP3 – The trophic ecology of canopy and litter ant assemblages via stable isotope analysis.			

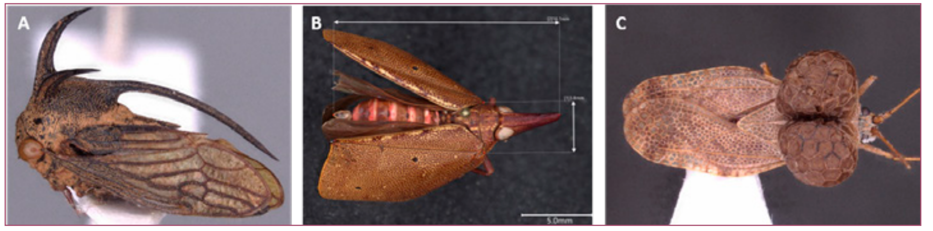
Kasmiatun Master student	Purnama Hidayat, IPB University	Stefan Scheu & Jochen Drescher– **Z02**	*Tropical land-use change effects on taxonomic and functional diversity of Hemiptera (True Bugs)*	Feb – Jul 2023

PROJECT SUMMARY

Summary/Description

Hemiptera, or True Bugs, are essential components of arthropod communities and the food webs of aboveground ecosystems. The Hemiptera fauna of Sumatra is little studied, and structured identification literature of photographic guides is missing. Furthermore, little is known about the effects of rainforest conversion to rubber and oil palm on Hemiptera communities in terms of taxonomic diversity, functional diversity or trophic compensation of whole communities. This ABS research project helps to close that knowledge gap by studying both taxonomic diversity of Hemiptera across said land-use change gradient, as well as the trophic ecology of the Hemiptera community by studying bulk stable isotopes (BSI) of 15N and 13C across the land uses. The aims are to lay the groundwork for the following goals: (1) High-resolution digital imagery of previously sorted master specimen of Hemiptera, using the KEYENCE VHX-7000 digital microscope. (2) Prepare selected samples of Hemiptera for bulk stable isotope (BSI) analysis, (3) Prepare a "Field Guide to the True Bugs of Jambi", and (4) analyze Hemiptera biodiversity and BSI data for publication in an international journal.

Picture 36A,B,C. Kasmiatun (A) taking images of Hemiptera specimen after taxonomic revision and mounting (B, C) at the Animal Ecology Group.



Picture 37A,B,C. Hemiptera specimen were photographed and measured under a digital microscope: *Leptocentrus taurus* (Auchenorrhyncha: Membracidae; A), an unidentified *Cyarda sp.* (Auchenorrhyncha: Flatidae; B), and an unidentified member of the Tinginae subfamily (Heteroptera: Tingidae; C).

Details and Results

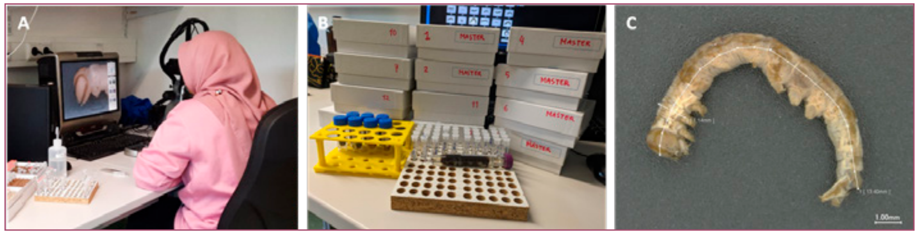
In two canopy fogging campaigns in EFForTS Core plots, dry season 2013 and rainy season 2013/14, Dr. Jochen Drescher collected ca. 35,000 Hemipterans in amongst ca. 800,000 arthropod specimen. A student group from Brawijaya University (under Dr. Akhmad Rizali) sorted 9200 specimen of Hemiptera to 480 morphospecies. Z02 research assistant Kasmiatun confirmed 391 of those morphospecies from at least 34 genera in 33 families (Pic. 36A). At Göttingen University, Kasmiatun brought the Hemiptera collection into a searchable storage format (2.5mL glass vials in 100-slot cryoboxes), and mounted a representative subset of the master specimen (Pic. 36B, 36C). Kasmiatun also prepared multi-focus photographs of 476 specimen of Hemiptera (Pic. 37A, 2B), and measured their body width and body length in preparation for biomass calculations and bulk stable isotope (BSI) analysis (Pic. 37C). We will conduct BSI on 167 individual samples, selected and assembled by Kasmiatun, which represent the most important Hemiptera families in each plot, for Auchenorrhyncha and the Heteroptera suborder, respectively. While BSI data is running, Kasmiatun will prepare the Field Guide to the True Bugs of Jambi", and thereafter, start with the analysis of species-abundance data and BSI data for a publication in an international journal.

Lia Nurulalia Master student	Purnama Hidayat, IPB University	Stefan Scheu & Jochen Drescher– **Z02**	*Tropical land-use change effects on taxonomic and functional diversity of Lepidoptera (Butterfly) larva)*	Feb – Jul 2023

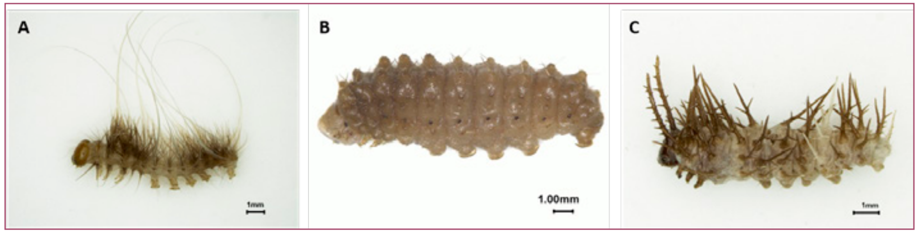
PROJECT SUMMARY

Summary/Description

Lepidoptera, or Butterflies, are essential components of arthropod communities and the food webs of aboveground ecosystems. The Lepidoptera fauna of Sumatra is little studied, and structured identification literature of photographic guides is missing. Furthermore, little is known about the effects of rainforest conversion to rubber and oil palm on butterfly communities in terms of taxonomic diversity, functional diversity or trophic compensation of whole communities, especially when larvae are concerned. This ABS research project helps to close that knowledge gap by studying both taxonomic diversity of butterfly larvae across said land-use change gradient, as well as the trophic ecology of the butterfly larva community by studying bulk stable isotopes (BSI) of 15N and 13C across the land uses. The aims are to lay the groundwork for the following goals: (1) High-resolution digital imagery of previously sorted master specimen of Lepidoptera caterpillars, using the KEYENCE VHX-7000 digital microscope. (2) Prepare selected samples of caterpillars for bulk stable isotope (BSI) analysis, (3) Prepare a "Field Guide to the Caterpillars of Jambi", and (4) analyze Lepidoptera caterpillar diversity and BSI data for publication in an international journal.



Picture 38A,B,C. Lia Nurulalia (A) taking images of Hemiptera specimen after taxonomic revision and structured deposition (B). Body sizes are measured digitally (C), even if specimen are curved.



Picture 39A,B,C. Taxonomy of sorted caterpillars was verified to family level, and supported by in-detail photography, e.g. of Erebidae (A), Lycaneidae (B) or Nymphalidae (C).

Details and Results:

In two canopy fogging campaigns in EFForTS Core plots, dry season 2013 and rainy season 2013/14, Dr. Jochen Drescher collected ca. 3500 Lepidoptera caterpillars. A student group from Brawijaya University (under Dr. Akhmad Rizali) sorted those to 26 families and more than 500 morphospecies. IPB University lecturer and Lepidoptera specialist Lia Nurulalia (Pic. 38A) confirmed 18 of the families in a thorough revision of almost 2500 specimen. At Göttingen University, Lia Nurulalia brought the caterpillar collection into a searchable storage format (2.5mL glass vials in 100-slot cryoboxes, Pic. 38B) and obtained body size measurements of all master specimen for biomass calculations and bulk stable isotope (BSI) analysis (Pic. 38C). Lia photographed more than 400 of the caterpillars in detail to prepare for the "Field Guide to the Caterpillars of Jambi" as well as digital documentation in Ecotaxonomy.org database (Pic. 39A, 39B, 39C). Lia also prepared 140 individual samples for BSI analysis, covering the most relevant Lepidoptera families in EFForTS Core plots. The data is already available, and awaits analysis in preparation for a publication in an international journal.

Ulfa Ulinnuha Master Student	Damayanti Buchori, IPB University	Stefan Scheu & Jochen Drescher– **Z02**	*Tropical land-use change effects on taxonomic and functional diversity of Diptera (Flies)*	Feb – Dec 2023

PROJECT SUMMARY

Summary/Description

Diptera, or Flies, are essential components of arthropod communities and the food webs of aboveground ecosystems. The Diptera fauna of Sumatra is little studied, and structured identification literature of photographic guides is missing. Furthermore, little is known about the effects of rainforest conversion to rubber and oil palm on Diptera communities in terms of taxonomic diversity, functional diversity or trophic compensation of whole communities. This ABS research project helps to close that knowledge gap by studying both taxonomic diversity of Diptera across said land-use change gradient, as well as the trophic ecology of the Diptera community by studying bulk stable isotopes (BSI) of 15N and 13C across the land uses. The aims are thus to lay the groundwork for the following goals: (1) High-resolution digital imagery of previously sorted master specimen of Diptera specimen, using the KEYENCE VHX-7000 digital microscope. (2) Prepare selected samples of Diptera for bulk stable isotope (BSI) analysis, (3) Prepare a "Field Guide to the Flies of Jambi", and (4) analyze Diptera diversity and BSI data for publication in an international journal.

Picture 40A,B,C. Ulfa Ulinnuha (A) taking images of Hemiptera specimen after structuring the collection systematically in ethanol and a mounted collection (B, C).

Picture 41A,B,C. Body sizes of flies are measured with a digital microscope, even if specimen are tiny, like Anthomyiids or Ceratopogonids (B). Large specimen such as Asilids (C) are sure to look god in a planned field guide.

Details and Results:

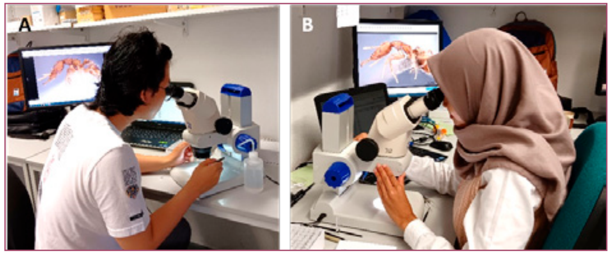
In two canopy fogging campaigns in EFForTS Core plots, dry season 2013 and rainy season 2013/14, Dr. Jochen Drescher collected ca. 37,000 Diptera specimen. A student group from Brawijaya University (under Dr. Akhmad Rizali), sorted those more than 900 morphospecies from 57 families. Focusing on data from the rainy season 2013/14 collection, Ulfa Ulinnuha (Pic. 40A) then revised the sorting of roughly 13,000 specimen, and confirmed about 400 species from 196 genera and 39 families. At Göttingen University, Ulfa then brought the Diptera collection into a searchable storage format (2.5mL glass vials in 100-slot cryoboxes, Pic. 40B) and mounted the majority of master specimens (Pic. 40C). Ulfa then measured the body lengths and widths of each of the 400 species with a digital microscope (Pic. 41A, 41B), to prepare for biomass calculations and bulk stable isotope (BSI) analysis. Ulfa prepared BSI analysis by selecting almost 300 individual samples of Diptera specimen representing the most dominant families in each of the EFForTS core plots, and placing them in individual, labelled vials. Ulfa also took more than 100 individual images to prepare the "Field Guide to the Flies of Jambi" (Pic. 41C).

Ferdian Master student **Rani Novita** Master student	Damayanti Buchori, IPB University	Stefan Scheu & Jochen Drescher– **Z02**	*Taxonomical identification of ants from the Landscape Assessment to morphospecies*	Jun – Nov 2023

PROJECT SUMMARY

Summary/Description/Results:

Ants are an integral part of terrestrial ecosystems, particularly in the tropics. To understand ant taxonomic and functional change in detail, sorting of specimen to species or morphospecies is necessary. Further, digital documentation of species and morphospecies is a crucial step in ensuring information sustainability and objectivity of produced data. This ABS research project helps to sort previously collected ants from the CRC990-EFForTS Landscape Assessment (EFForTS-LA) to species and morphospecies, and to document them in the Ecotaxonomy.org database and an update to an existing field guide to the ants of Jambi. The aims are: (1) Sort all ant individuals from EFForTS Core Plots and 8 randomly selected shrubland plots to morphospecies. (2) Update relevant entries in Ecotaxonomy.org and update "A Guide to the Ants of Jambi (Sumatra, Indonesia). (3) Prepare bulk stable isotope (BSI) analysis of the ant communities in those plots. The latter will provide the data basis for an analysis of functional changes in ant communities with land-use change, both from litter and canopy, to be published in an international journal. In a preliminary ID, there are 74 genera of ants in the leaf litter, and 46 genera in the canopy. Rani Novita and Ferdian are currently sorting ant specimen from canopy and litter from Core plots and eight randomly selected shrbland sites to species (Pic. 42A, B).



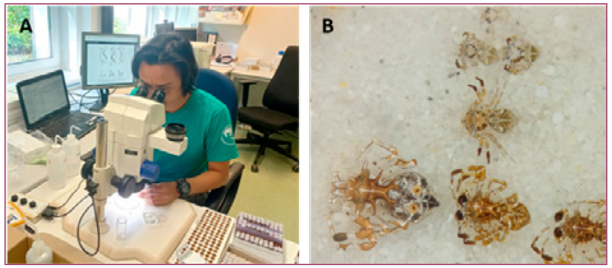
Picture 42A,B. Ferdian (A) and Rani Novita (B) are checking species ID of ants from the genus *Strumigenys*.

Naufal Urfi Master student	Damayanti Buchori, IPB University	Stefan Scheu & Jochen Drescher– **Z02**	*Improving the taxonomic resolution of canopy spiders and their online documentation*	Jun – Nov 2023

PROJECT SUMMARY

Summary/Description/Results:

Spiders (Arthropoda: Araneae) are key predators of aboveground terrestrial ecosystems. Within the CRC990-EFForTS research framework, the subproject Z02-WP3 "Monitoring of Aboveground Animal Biodiversity" has quantified canopy spider taxonomic and phylogenetic diversity decline across the land-use gradient from rainforest to rubber and oil palm monoculture plantations of both the 2013 and the 2017 sampling campaign. During a revision of the spider collection for an anticipated Field Guide on the Spiders of Jambi, it became clear that substantial updates are necessary to update the physical collection currently in the Animal Ecology Department at Göttingen University, as well as the digital information available on Ecotaxonomy.org. Aproximately 10,000 specimen of arboreal spiders are currently being checked thoroughly for species ID (Pic. 43A, B), with focus on spider taxa in which experts might describe new species.



Picture 43A,B. Naufal Urfi Dhiya'Ulhaq (A) is busy revising an existing collection of spiders. He is giving special attention to sexual dimorphisms, and juvenile forms (B).

2 B. ABS – SCHOLARSHIPS FOR TWO MASTER STUDIES OF STAKEHOLDERS

In 2022 and 2023, EFForTS supported the master studies of two stakeholders at Jambi University.

Name of student	Affiliation Indonesia	Study program	Title of thesis	Funding period
Ardiansyah	Harapan Rainforest	Faculty of Law, Jambi University	*Legal protection for ecosystem restoration concession forest areas (Case study: Concession areas of PT Restorasi Ecosystem Indonesia).* *Perlindungan Hukum Terhadap Kawasan Hutan Areal Konsesi Restorasi Ekosistem (Studi Kasus: Areal Konsesi Pt Restorasi Ekosistem Indonesia*	2021 – 2023
Asri Buliyansih	National Park Bukit Duabelas	Environmental Sciences, Faculty of Agriculture, Jambi University	*Status of sustainability of food consumption patterns of the Suku Anak Dalam tribe (SAD) at Resort II.E Air Hitam I Bukit Duabelas National Park* *Status Keberlanjutan Pola Konsumsi Pangan Suku Anak Dalam (SAD) Di Resort II.E Air Hitam I Taman Nasional Bukit Duabelas*	2021 – 2023 Inauguration: May 20, 2023

ABSTRACT

Suku Anak Dalam (SAD) are indigenous people who live in and around the Bukit Duabelas National Park and who, as they interact with the surrounding community, experience changes, including in food consumption patterns. This study examines SAD food consumption patterns by analyzing demographic and socio-economic characteristics as well as the sustainability status of these food consumption patterns in the TNBD area. This study was conducted at Resort II.E. Air Hitam I Bukit Duabelas National Park with 73 household heads coming from 4 SAD groups living in this area, namely Temenggung Grip, Nangkus, Bepayung, and Afrizal groups, in October– November 2022. This research method is quantitative with a cross-sectional research design. The results of the study show that the demographic and socio-economic characteristics of SAD are: (1) the dominant ages ranging from 15 to 60 years; (2) more than 50% have no education; (3) the average current job is farming; and (4) the average income is around Rp. 2,400,000/month. The pattern of food consumption is expressed by the energy adequacy rate (AKE) and protein adequacy rate (AKP) with magnitudes of 1695,97 kcal/cap/day and 56,11 gr/cap/day, which are in the sufficient category, meaning 80–100% of the AKP or AKE is fulfilled. Sustainability analysis of food consumption patterns is carried out on four dimensions, namely health, ecology, socio- culture, and economy, with multidimensional sustainability index values in the range of 43–47 percent, which fall into the less sustainable category.

Picture 44a+b. Inauguration of Asri Buliyansih on May 20, 2023 at Jambi University.

3. ABS – CAPACITY BUILDING WORKSHOPS IN 2022 AND 2023

1. 2nd Workshop on Tropical Plant Identification – Oct 31 to Nov 5, 2022 – SEAMEO-BIOTROP, Bogor, Indonesia.
   - In mega-diverse countries like Indonesia, recognizing and identifying species is often challenging. Yet, correct species identification is the foundation not only for research on organisms and ecosystems but also for the sustainable management of biological resources. Hence, the ability to correctly identify species is a key skill for researchers, forest and agricultural managers and conservation practitioners.
   - Fabian Brambach (B06, postdoctoral researcher) joined forces with colleagues from Indonesia (BRIN and Universitas Samudra) and the Royal Botanic Gardens Kew (UK) to hold a training workshop on plant identification. Twenty-six participants from universities, research institutions, protected area administrations, and NGOs all over Indonesia and the Philippines took part in the workshop. The majority of the participants came from the EFForTS partners IPB, UNJA UNTAD, PT. REKI, TNBD, and BRIN, complemented by staff from institutions in peripheral areas that usually have little access to international workshops.
   - The workshop was held at SEAMEO-BIOTROP in Bogor, an ideal place thanks to the herbarium run by B06 counterpart Dr. Sri S. Tjitrosoedirdjo and her team and the large collection of living plants on the extensive campus.
   - The 6-day workshop started with an opening ceremony followed by a lecture on general topics regarding plant identification and detailed presentation of 33 selected families, including many species of economic, ecological, cultural, spiritual, or aesthetic value. After each participant received two helpful books, The Kew Tropical Plant Families Identification Handbook and the Kew Plant Glossary, they were ready for the hands-on practical sessions following the lectures. In these sessions, the participants were able to become familiar with their flora using dried herbarium specimens and fresh material, sourced every day from the BIOTROP campus by the dedicated staff. Many techniques and tricks were shared between lecturers and participants and lively discussions took place. In order to see plants in their natural habitat as well, two trips were undertaken: One to Gunung Gede-Pangrango National Park where the group hiked through beautiful mountain rain forest to the Cibereum Waterfall. Most families treated in the course were found along way, so that the walking speed was quite slow – as usual for botanists. On the last day, another visit was paid to the famous Bogor Botanical Garden where, however, the walk was interrupted by heavy

Picture 45. Banner of the Training Workshop on Tropical Plant Identification 2022 in SEAMEO-BIOTROP, Bogor, Indonesia.

Pictur 46. Participants came from all across Indonesia and the Philippines.

Picture 47. Before the exam, all participants had the chance to repeat the characters of all plant families treated in the workshop based on specimens from BIOTROP's herbarium and EFForTS researchers. From left to right: Ade Adriadi, Asih Rahayu Ajeng Agesti, Jimmy Frans Wanma, Esi Resida, and Atus Syahbudin.

Picture 48. Group picture of all participants, lecturers, and instructors of the 2022 tropical plant identification workshop. Standing in front of stairs (from left to right): Mei Linda Mardalena, Wendy A. Mustaqim, Wisnu H. Ardi, André Schuiteman, Fabian Brambach, Alex Sumadijaya. Standing on stairs: Saiful Bachri, Mohammad Iqbal, Roland Ahmad, Harry Imantho, Ainulyakin Hasan Imlani, Fauriza J. Saddari, Zulhamsyah Imran, Carmen Puglisi, Laura Jennings, Pieter Agusthinus Riupassa, Jimmy Frans Wanma, Iswanto, Andriani Ninda Momo, Ade Adriadi. Standing on platform: Hani Ristiawan, Dery Yandi, Muhammad Rifqi Hariri, Afri Irawan, Sai'in, Dirga Shabri Pradana, Mami Dewi, Esi Resida, Indah Wahyuni, Asri Rahayu Ajeng Agesti, Deby Arifiani, Linda Oktavianingsih, Wira Dharma, Asri Buliyansih, Inna Puspa Ayu, Mahya Ihsan, Sukiman, Atus Syahbudin, Eddy Nurtjahya

rain. Finally, the participants took an exam where they had to recognize one representative of each family treated. Exam results varied widely but most participants got the majority of families right.

- As in most countries, in Indonesia there is currently a lack of skilled botanists and in addition a strong concentration of botanical expertise in Java. The workshop was an ideal opportunity for aspiring botanists from Java but also other regions of Indonesia and the Philippines to learn about plant identification. At the same time, it was also a chance to meet and connect to colleagues with similar interests, help each-other with advice, and discuss about plant identification, conservation, and management. Follow-up collaboration projects between some of the participants and the lecturers in Indonesia and abroad have already started as a result of the workshop.
- The workshop received very positive feedback from the participants and the lecturers alike and interest for a repetition or rather continuation of the training was voiced by several.

The organizers would like to thank all participants and lecturers, the fantastic team at BIOTROP under the guidance of Dr. Sri S. Tjitrosoedirdjo, and the EFForTS coordination offices in Bogor, Jambi, and Göttingen, all of whom worked together to make this activity a success.

2. Teaching materials for environmental education and sustainable development goals: Using CBL as a case-method and PjBL as a team-based project implementation model
    - On November 21 and 22, 2022 Rayandra Asyhar Vice rector for Planning, Collaboration Affairs and Information systems, and Sudarmin, both from Jambi University, introduced models for the implementation of CBL and PjBL for 70 lecturers working in the field of environmental and sustainable development.

Figure 61. Flyer Teaching materials for environmental education.

Picture 49. Workshop on Nov 21, 2022 at Bank 9 Jambi.

Picture 50. Workshop on Nov 23, 2022 at Jambi University

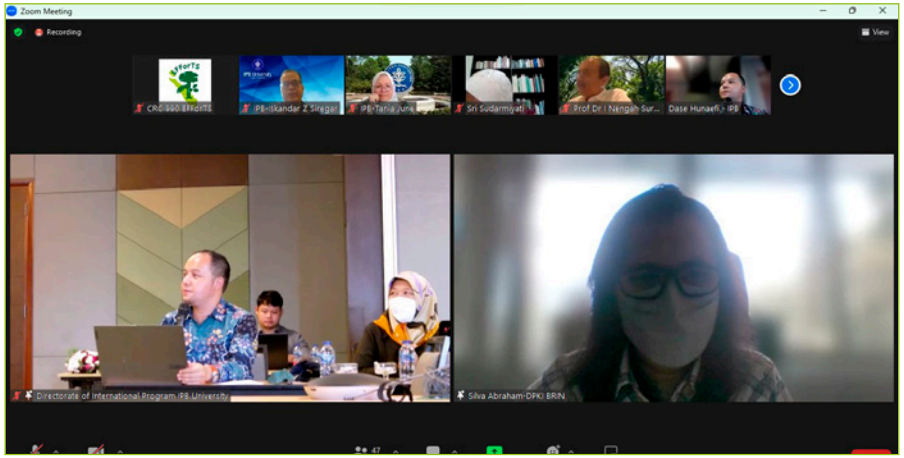
3. International Research Collaboration: Challenges and Opportunities

- The hybrid workshop was carried out on November 30, 2022 at UNTAD with the aim to identify strategies and ways for the improvement of international research collaboration. Mahfudz, the rector of UNTAD, opened the hybrid workshop for 180 academic staff from various universities in Indonesia, among others, Prof. Sutrisno, Rector of Jambi University.
- Presenter:
  - Nizam (Director General of DIKTI),
  - Agus Haryono (Deputy of BRIN),
  - Dodik Nurrochmat (Spokesperson of EFForTS),
  - Aiyen Tjoa (Vice rector UNTAD & Head Coordinator EFForTS Indonesia).

Picture 51. ABS workshop, held on November 30, 2022.

4. International Research to support Central Biodiversity Data

- The workshop (hybrid) was carried out on 14 December 2022 at the ICC of IPB University.
- Aim: To prioritize and advance the development of biodiversity data to support economic growth.
- Presenter:
  - Silva Abraham (Director Management of Scientific Collections, BRIN). Topic: Development of Biodiversity Science Collection - Trend, Access and Utilization.
  - Fifin Nopiansyah (Director KKHGS, Ministry of Environment and Forestry). Topic: Indonesian Policy in Biodiversity Database Reinforcement.
  - Aiyen Tjoa (Universitas Tadulako). Topic: Lesson learned: Research partnership and data management.
  - Try Surya Harapan (Herbarium Universitas Andalas). Topic: Lessons Learned - Open Access Data Biodiversity.

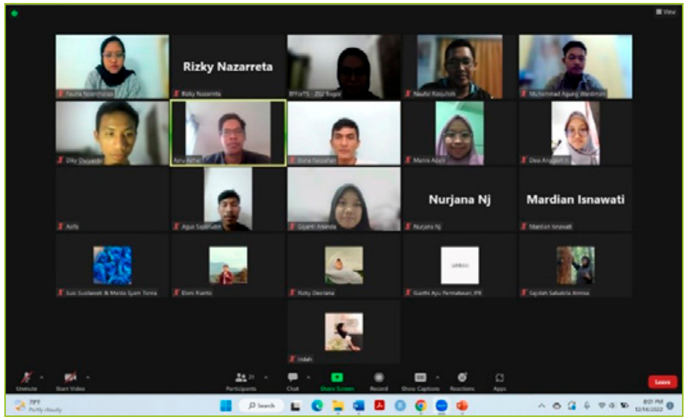


Picture 52. ABS Workshop on 14 December 2022.

5. Learn Statistic using RStudio for Data Science
   - The five-day workshop (hybrid) was held from December 12–17, 2022 at IPB University.
   - Aim: To improve capacity building among Indonesian young scientist and to support EFForTS mission to accelerate knowledge through applied-science
   - Twenty-one participants attended the workshop: 11 assistants from EFForTS (B14, C07, C08, Z02), and 10 staff from IPB University.

6. Young Researcher Forum 2022
   - On December 17, 2022 the Young Researcher Forum took place online with the objective to motivate young scholars to present their research ideas in public and to enhance their presentation skills.
   - Of the 20 participants, several young researchers have received awards.
   - Nominated as best presenters were:
     - First place: Nitya Ade Santi & Sajidah Salsabila Annisa
     - Second place: Fauzia Noorchaliza & Desi Anggrahini
     - Third place: Bonauli Pakpahan & Nurjana
   - Best abstract:
     - Marini Adani
   - Favorite presenter:
     - Putri Afin Nurhayati & M. Agung Wardiman

7. Managing International Research Collaboration & Research Import and Export Regulation
   - The workshop (hybrid) was held on January 17, 2023 at IPB University to provide information on current export and import regulations for scientific goods in order to support international collaboration.
   - Presenter:
     - Dr. Yessi Vadila (Ministry of Trade): Export policy for research from the Ministry of Trade
     - Bapak Syifullah and Bapak Yusli (Indonesian Customs): Introduction to the customs system
     - Bapak Rasyid (Ministry of trade): Indonesian Single Window- systems for export



Picture 53. Young Researcher Forum 2022.

Picture 54. ABS workshop on 17 January 2023.
Dr. Yessie Vadila talked about export regulations.

8. Undergraduate student essay contest: The challenges and opportunities ahead on economic growth and its impact on sustainable development (Fig. 62)

- The objective of the competition was to offer young people a platform to engage in discussions and share their insights regarding the economic growth prospects and how they can be balanced with sustainable development.
- The twelve best essayists have been awarded a one-week research stay in the field sites of EFForTS from July 7 to 13, 2023. The winners were:
  - UNTAD: Balqis Amalia, Moh. Syafaril Adam, Komang Putra
  - IPB University: Nurwahid Dimas Saputro, Adila Hasanah, Desi Anggrahini, Miranda Octaviana Ilham
  - UNJA; Anas Ridho Muhadzdzib, Amir Hamzah, Muhammad Rizky Ramadhan, Iwan Larson Limbong, Rahmad Dzaki

Picture 55. Visit of the Gentala Arasy Bridge, a iconic place in Jambi city.

Picture 57. Ibu Sri Sudarmiyati together with Dian Muh Fauzan and Edo Mauliarta from B06 gave the 12 winners a presentation about the identification and collection of flora in Jambi.

Picture 56. Introduction to PT Reki

Picture 58. The 12 winners visited the Climate Tower at PTPN VI.

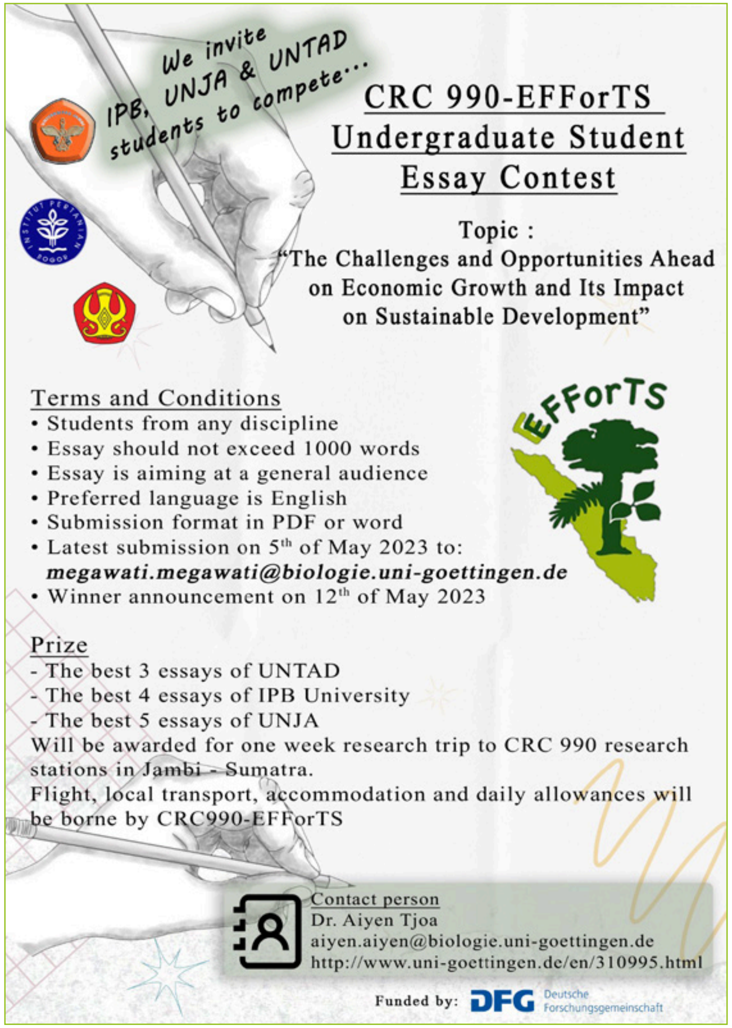


Figure 62

Picture 59. At the BEE research plots.

Picture 60. Visit of the EFForTS research plots in PT REKI.

9. Building International Capacity Management: Beyond 12 years of CRC990-EF-ForTS (Figure 63).

- The workshop will take place at UNTAD on September 14, 2023. It will reflect on a) the accomplishments and lessons learned from EFForTS, and b) regulations concerning international research collaboration.
- Speakers are: Prof. Nizam (Director DIKTIRISTEK), Prof. Agus Haryono (Deputy for Research and Innovation Facilities at the National Research and Innovation Agency (BRIN)), Prof. Faiz Syuaib (Director of Research and Community Service, RISTEK), Prof. Muhammad Miftahussurur (Chairman FORWAREK Co-operation), and Dr. Aiyen Tjoa (Vice-Rector of Collaboration Affairs, UNTAD).
- The opening of the workshop is by Prof. Amar, Rector of UNTAD, and the closing remarks are given by Prof. Iskandar Siregar, Vice-Rector of IPB University.

Figure 63

4. PUBLICATIONS ORIGINATING FROM ABS PROJECTS

A03 A07	**Artika**, **June T, Salmayenti R, Sugiarto Y, Handoko, Stiegler C, Knohl A** (2023) Estimation of Oil Palm Total Carbon Fluxes Using Remote Sensing; Agromet *https://journal.ipb.ac.id/index.php/agromet/article/view/44710*
A03 A07	**Aulia FR**, **June T, Koesmaryono Y** (2022) Increasing smoghaze and its impact on oil palm evapotranspiration and gross primary production during the 2015 fire: special discussion on diffuse radiation; Journal of Natural Resources and Environmental Management *https://journal.ipb.ac.id/index.php/jpsl/article/view/40214*
Z02 B10 B09	**Azhar A**, **Tawakkal MI, Sari A, Rizali A, Tarigan SD, Nazarreta R, Buchori D** (2022) Tree diversity enhance species richness of beneficial insect in experimental biodiversity enrichment in oil palm plantation; International Journal of Oil Palm 5: 39-49 *https://ijop.id/index.php/ijop/article/view/82*
Z02	**Azhar A, Hartke TR, Bottges L, Lang T, Larasati A, Novianti N, Tawakkal I, Hidayat P, Buchori D, Scheu S, Drescher J** (2022) Rainforest conversion to cash crops reduces abundance,biomass and species richness of parasitoid wasps in Sumatra,Indonesia; Agricultural and Forest Entomology *https://resjournals.onlinelibrary.wiley.com/doi/10.1111/afe.12512*
Z02	**Buchori D, Hidayat P, Nazarreta R, Ardiyanti RM, Siddikah F, Amrulloh R, Azhar A, Kasmiatun, Scheu S, Drescher J** (2022) Keanekaragaman Serangga Hutan Hujan Tropis Dataran Rendah di Provinsi Jambi, Sumatra: Dampak Perubahan Tata Guna Lahan; e-Publishing, Penerbit BRIN, ISBN-13 (15) 978-602-496-282-1 *https://penerbit.brin.go.id/press/catalog/book/280*
Z02	**Hidayat P**, **Siddikah F, Kasmiatun, Noerdjito WA, Amrulloh R, Hiola MS, Najmi L, Nazarreta R, Scheu S, Buchori D, Drescher J** (2022) Guidebook of beetles and weevils of Jambi, Sumatra, Indonesia; e-Publishing Penerbit BRIN, ISBN-13 (15) 978-623-7425-71-7 *https://penerbit.brin.go.id/press/catalog/book/321*
B04 B06	**Jamaluddinsyah**, **Sulistijorini, Waite PA, Kotowska MM, Brambach F, Schuldt B, Triadiati** (2022) Tree height effects on vascular anatomy of upper-canopy twigs across a wide range of tropical rainforest species; Journal of Tropical Ecology 38: 416-425 *https://www.cambridge.org/core/journals/journal-of-tropical-ecology/article/tree-height-effects-on-vascular-anatomy-of-uppercanopy-twigs-across-a-wide-range-of-tropical-rainforest-species/02A7370C3EC710777BD2795BECE3F27E*
A03 A07	**Ma'allimah Z**, **June T, Salmayenti R, Sugiarto Y, Handoko, Stiegler C, Knohl A** (2023) Micrometeorological Method in Determining Plant Capacity to Absorb Pollutant: Oil Palm Case Study; Agromet *https://journal.ipb.ac.id/index.php/agromet/article/view/44711*
A07	**Ma'rufah U**, **Tania JT, Ali AA, Akhmad FA, Koesmaryono Y, Stiegler C, Knohl A** (2022) Vulnerability of Primary Productivity and Its Carbon Use Efficiency to Unfavorable Climatic Conditions in Jambi Province, Indonesia; Journal of Mathematical & Fundamental Sciences 54 *https://journals.itb.ac.id/index.php/jmfs/article/view/16635*
Z01	**Rahmani TA**, **Nurrochmat DR, Park MS, Boer R, Ekayani M, Satria A** (2022) Reconciling Conflict of Interest in the Management of Forest Restoration Ecosystem: A Strategy to Incorporate Different Interests of Stakeholders in the Utilization of the Harapan Rainforest, Jambi, Indonesia; Sustainability *https://www.mdpi.com/2071-1050/14/21/13924*
B14	**Wardani IGAK**, **Armandita FY, Moura CCM, Gailing O, Siregar IZ** (2022) Molecular taxonomy via DNA barcodes for species identification in selected genera of Fabaceae; Journal of Natural Ressources and Environmental Management 12 *https://journal.ipb.ac.id/index.php/jpsl/article/view/36609*
B14 B06	**Wati R**, **Amandita FY, Brambach F, Siregar IZ, Gailing O, Carneiro de Melo Moura C** (2022) Filling gaps of reference DNA barcodes in Syzygium from rainforest fragments in Sumatra; Tree Genetics & Genomics 18:6 *https://link.springer.com/article/10.1007/s11295-022-01536-z*

IV. Publications

1. **Journal articles (275)**
2. **Reviews (22)**
3. **Other Publications (30)**
4. ***EFForTS* Discussion Paper Series (37)**
5. **Submitted**

Since the beginning of the project in 2012, EFForTS has published 364 articles, of which 61 are first-authored by counterparts or junior researchers from Indonesia. Overall, 263 articles are disciplinary papers, published by one subproject, and 83 articles are interdisciplinary ones, published by two (59) or more than two (41) subprojects.

Tables 1 to 5 show the scientific publications of EFForTS since the last issue of newsletter no. 8, July 2022.

1. JOURNAL ARTICLES published since June 2022

C02	**Brad A**, **Hein J** (2022) Towards transnational agrarian conflicts? Global NGOs, transnational agrobusiness and local struggles for land on Sumatra; New Political Economy 28 *https://www.tandfonline.com/doi/full/10.1080/13563467.2022.2138300*
C08	**Brenneis K, Bambang I, Wollni M** (2023) Promoting agricultural technologies with positive environmental effects: Evidence on tree planting in Indonesia; Ecology Economics 204: 107666 *https://www.sciencedirect.com/science/article/pii/S0921800922003275*
C07	**Chrisendo D, Siregar H, Qaim M** (2022) Oil palm cultivation improves living standards and human capital formation in smallholder farm households; World Development 159: 106034 *https://www.sciencedirect.com/science/article/pii/S0305750X22002248*
B08	**Eisenhauer N, Bender SF, Calderón-Sanou I, de Vries FT, Lembrechts JJ, Thuiller W, Wall DH, Zeiss R, Bahram M, Beugnon R, Burton VJ, Delgado-Baquerizo M, Geisen S, Kardol P, Krashevska V, Martínez-Muñoz CA, Patoine G, Seeber J, Soudzilovskaia N, Steinwandter M, Sünnemann M, Sun X, Guerra CA, Potapov A** (2022) Frontiers in soil ecology - insights from the World Biodiversity Forum 2022; Journal of Sustainable Agriculture and Environment 1: 245-261 *https://onlinelibrary.wiley.com/doi/10.1002/sae2.12031*
B08	**Ermilov SG, Sandmann D, Scheu S** (2023) New Otocepheidae (Acari, Oribatida) from Indonesia; International Journal of Acarology *https://www.tandfonline.com/doi/full/10.1080/01647954.2023.2215257*
B08	**Ermilov SG, Sandmann D, Scheu S** (2023) New species of Pulchroppia (Acari, Oribatida, Oppiidae) from Indonesia; Acarologia 63: 725-734 *https://www1.montpellier.inra.fr/CBGP/acarologia/article.php?id=4626*
B08	**Ermilov SG, Sandmann D, Scheu S** (2023) New species of oribatid mites (Acari, Oribatida) with auriculate pteromorphs from Indonesia; Systematic and Applied Acarology 28: 1043–1055 *https://www.biotaxa.org/saa/article/view/81464*

Associated project Prof. Sauer, B04, B06	**Greenshields B, von der Lühe B, Schwarz F, Huges HJ, Toja A, Kotowska M, Brambach F, Sauer D** (2023) Estimating oil-palm Si storage, Si return to soils and Si losses through harvest in smallholder oil-palm plantations of Sumatra, Indonesia; Biogeosciences 20: 1259-1276 *https://bg.copernicus.org/articles/20/1259/2023/bg-20-1259-2023.html*
Associated project Prof. Sauer, A03	**Greenshields B, von der Lühe B, Huges HJ, Stiegler C, Tarigan S, Toja A, Sauer D** (2023) Oil-palm management alters the spatial distribution of amorphous silica and mobile silicon in topsoils; SOIL 9: 169-188 *https://soil.copernicus.org/articles/9/169/2023/*
Associated project Prof. Sauer, A04, A05	**Greenshields B, von der Lühe B, Huges HJ, Tjoa A, Hennings N, Sauer D** (2023) Effects of turning rainforest into oil-palm plantations on silicon pools in soils within the first 20 years after the transformation; Frontiers in Environmental Science 11:1189502 *https://www.frontiersin.org/articles/10.3389/fenvs.2023.1189502/full*
Associated project Prof. Sauer, A03	**Greenshields B, von der Lühe B, Huges HJ, Stiegler C, Tarigan S, Toja A, Sauer D** (2023) Oil-palm management alters the spatial distribution of amorphous silica and mobile silicon in topsoils; SOIL 9: 169-188 *https://soil.copernicus.org/articles/9/169/2023/*
B10, B06, B14	**Halmschlag CB, Moura CCM, Brambach F, Siregar IZ, Gailing O** (2022) Molecular and morphological survey of Lamiaceae species in converted landscapes in Sumatra; PLoS ONE 17: e0277749 *https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0277749*
C12	**Husmann K, von Groß V, Bödeker K, Fuchs JM, Paul C, Knoke T** (2022) optimLanduse: A package for multiobjective land-cover composition optimization under uncertainty; Methods in Ecology and Evolution 13: 2719-2728 *https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.14000*
A05, B02, B06, B08, B09, Z01	**Iddris NA-A, Formaglio G, Paul C, von Groß V, Chen G, Angulo-Rubiano A, Berkelmann D, Brambach F, Darras KFA, Krashevska V, Potapov A, Wenzel A, Irawan B, Damris M, Daniel R, Grass I, Kreft H, Scheu S, Tscharntke T, Verldkamp E, Corre MD** (2023) Mechanical weeding enhances ecosystem multifunctionality and profit in industrial oil palm; Nature Sustainability 6: 683–695 *https://www.nature.com/articles/s41893-023-01076-x*
B04, B06	**Jamaluddinsyah, Sulistijorini, Waite PA, Kotowska MM, Brambach F, Schuldt B, Triadiati** (2022) Tree height effects on vascular anatomy of upper-canopy twigs across a wide range of tropical rainforest species; Journal of Tropical Ecology 38: 416-425 *https://www.cambridge.org/core/journals/journal-of-tropical-ecology/article/tree-height-effects-on-vascular-anatomy-of-uppercanopy-twigs-across-a-wide-range-of-tropical-rainforest-species/02A7370C3EC710777BD2795BECE3F27E*
Z02	**Kasmiatun, Hartke TR, Buchori D, Hidayat P, Siddikah F, Amrulloh R, Hiola MS, Najmi L, Noerdjito WA, Scheu S, Drescher J** (2022) Rainforest conversion to smallholder cash crops leads to varying declines of beetles (Coleoptera) on Sumatra: Biotropica 55: 119-131 *https://onlinelibrary.wiley.com/doi/10.1111/btp.13165*
B04, A03, A05	**Kotowska MM, Samhita S, Hertel D, Triadiati, Beyer F, Allen K, Link RM, Leuschner C** (2023) Consequences of tropical rainforest conversion to tree plantations on fine root dynamics and functional traits; Oikos: e08898 *https://onlinelibrary.wiley.com/doi/10.1111/oik.08898*
B08, A03, Z02	**Krashevska V, Stiegler C, June T, Widyastuti R, Knohl, Scheu S, Potapov A** (2022) Land-use change shifts and magnifies seasonal variations of the decomposer system in lowland tropical landscapes; Ecology and Evolution 12: e9020 *https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.9020*

B09, B11	**Li K, Grass I, Zemp DC, Lorenz H, Sachsenmaier L, Nurdiansyah F, Hölscher D, Kreft H, Tscharntke T** (2023) Tree identity and canopy openness mediate oil palm biodiversity enrichment effects on insect herbivory and pollination; Ecological Applications 33: e2862 *https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2862*
A07	**Ma'rufah U, Tania JT, Ali AA, Akhmad FA, Koesmaryono Y, Stiegler C, Knohl A** (2022) Vulnerability of Primary Productivity and Its Carbon Use Efficiency to Unfavorable Climatic Conditions in Jambi Province, Indonesia; Journal of Mathematical & Fundamental Sciences 54 *https://journals.itb.ac.id/index.php/jmfs/article/view/16635*
Z02	**Mawan A, Hartke TR, Deharveng L, Zhang F, Buchori D, Scheu S, Drescher J** (2022) Response of arboreal Collembola communities to the conversion of lowland rainforest into rubber and oil palm plantations; BMC Ecology and Evolution 22: 144 *https://bmcecolevol.biomedcentral.com/articles/10.1186/s12862-022-02095-6*
B11, B02, B06, B07, B08, B09, B13	**Montoya-Sánchez V, Kreft H, Arimond I, Ballauf J, Berkelmann D, Brambach F, Daniel R, Grass I, Hines J, Hölscher D, Irawan B, Krause A, Polle A, Potapov A, Sachsenmaier L, Scheu S, Sundawati L, Tscharntke T, Zemp DC, Guerrero-Ramírez N** (2023) Landscape heterogeneity and soil biota are central to multi-taxa diversity for oil palm landscape restoration; Communications Earth & Environment 4: 209 *https://www.nature.com/articles/s43247-023-00875-6*
A01	**Nguyen CH, Setyaningsih CI, Jahnk SL, Saad A, Sabiham S, Behling H** (2022) Forest dynamics and agroforestry history since AD 200 in the highland of Sumatra, Indonesia; Forest 19: 1473 *https://www.mdpi.com/1999-4907/13/9/1473*
A01	**Nguyen CH, Hapsari KA, Saad A, Sabiham S, Behling H** (2023) Late Holocene riparian vegetation dynamics, environmental changes, and human impact in the Harapan forest of Sumatra, Indonesia; Frontiers in Ecology and Evolution 11: 1-14 *https://www.frontiersin.org/articles/10.3389/fevo.2023.1224160/full*
Z02, B08	**Pollierer MM, Drescher J, Potapov A, Kasmiatun, Mawan A, Mutiari M, Nazarreta R, Hidayat P, Buchori D, Scheu S** (2023) Rainforest conversion to plantations fundamentally alters energy fluxes and functions in canopy arthropod food webs; Ecology Letters *https://onlinelibrary.wiley.com/doi/10.1111/ele.14276*
B09	**Potapov AM,** **Beaulieu F, Birkhofer K, Bluhm SL, Bryndova M, Devetter M, Goncharov AA, Gongalsky KB, Klarner B, Korobushkin DI, Liebke D, Maraun M, McDonnell R, Pollierer MM, Schmidt O, Schrubovich J, Semenyuk II, Sendra A, Tuma J, Vassilieva A, Chen T-W, Beaulieu F, Geisen S, Tiunov AV, Scheu S** (2022) Feeding habits and multifunctional classification of belowground consumers from protists to vertebrates; Biological Reviews 97: 1057-1117 *https://onlinelibrary.wiley.com/doi/10.1111/brv.12832*
B08	**Potapov AM, Guerra CA, van den Hoogen J, Babenko A, Bellini BC, Berg MP, Chown SL, Deharveng L, Kováč Ľ, Kuznetsova NA, Ponge J-F, Potapov MB, Russell DJ, Alexandre D, Alatalo JM, Arbea JI, Bandyopadhyaya I, Bernava V, Bokhorst S, Bolger T, Castaño-Meneses G, Chauvat M, Chen T-W, Chomel M, Classen AT, Cortet J, Čuchta P, de la Pedrosa AM, Ferreira SSD, Fiera C, Filser F, Franken O, Fujii S, Koudji EG, Gao M, Gendreau-Berthiaume B, Gomez-Pamies DF, Greve M, Handa IT, Heiniger C, Holmstrup M, Homet P, Ivask M, Janion-Scheepers C, Jochum M, Joimel S, Jorge BCS, Jucevica E, Ferlian O, de Oliveira Filho LCI, Klauberg-Filho O, Baretta D, Krab EJ, Kuu A, de Lima ECA, Lin D, Lindo Z, Liu A, Lu J-Z, Luciañez MJ, Marx MT, McCary MA, Minor MA, Nakamori T, Negri I, Ochoa-Hueso R, Palacios-Vargas JG, Pollierer MM, Querner P, Raschmanová N, Rashid MI, Raymond-Léonard LJ, Rousseau L, Saifutdinov RA, Salmon S, Sayer EJ, Scheunemann N, Scholz C, Seeber J, Shveenkova YB, Stebaeva SK, Sterzynska M, Sun X, Susanti WI, Taskaeva AA, Thakur MP, Tsiafouli MA, Turnbull MS, Twala MN, Uvarov AV, Venier LA, Widenfalk LA, Winck BR, Winkler D, Wu D, Xie Z, Yin R, Zeppelini D, Crowther TW, Eisenhauer N, Scheu S** (2023) Globally invariant metabolism but density-diversity mismatch in springtails; Nature Communications 14: 674 *https://www.nature.com/articles/s41467-023-36216-6*

Z02	**Ramos D, Hartke TR, Buchori D, Dupérré N, Hidayat P, Lia M, Harms D, scheu S, Drescher J** (2022) Rainforest conversion to rubber and oil palm reduces abundance, biomass and diversity of canopy spiders; PeerJ 10:e13898 *https://peerj.com/articles/13898/*
B14	**Ryadi A, Siregar I, Moura CCM, Gailing O, Amandita FY** (2023) An Early Reference to DNA Barcode for the Anacardiaceae Family; HAYATI Journal of Biosciences 30: 543-550 *https://journal.ipb.ac.id/index.php/hayati/article/view/42640*
Z02, A03, B09	**Schlund M, Wenzel A, Camarretta N, Stiegler C, Erasmi S** (2022) Vegetation canopy height estimation in tropical landscapes with TanDEM-X supported by GEDI data; Methods in Ecology and Evolution 14: 1639-1656 *https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.13933*
C10, INF	**Seufert JD, Python A, Weisser C, Cisneros E, Kis-Katos K, Kneib T** (2022) Mapping ex ante risks of COVID-19 in Indonesia using a Bayesian geostatistical model on airport network data; Journal of the Royal Statistical Society: Series A (Statistics in Society) 185: 2121–2155 *https://academic.oup.com/jrsssa/article/185/4/2121/7069384*
C07	**Sibhatu KT** (2023) Oil Palm Boom: Its Socioeconomic Use and Abuse; Frontiers in Sustainable Food Systems 7 *https://www.frontiersin.org/articles/10.3389/fsufs.2023.1083022/abstract*
B10	**Simpkins CE, Hanß S, Spangenberg MC, Salecker J, Hesselbarth MHK, Wiegand K** (2022) spectre: an R package to estimate spatially-explicit community composition using sparse data; Ecography 2022: e06272 *https://onlinelibrary.wiley.com/doi/10.1111/ecog.06272l*
A03, A05, Z02	**Stiegler C, Koebsch F, Ali AA, June T, Veldkamp E, Corre MD, Koks J, Tjoa A, Knohl A** (2023) Temporal variation in nitrous oxide (N2O) fluxes from an oil palm plantation in Indonesia: An ecosystem-scale analysis; Bioenergy *https://onlinelibrary.wiley.com/doi/10.1111/gcbb.13088*
C07	**Tabe-Ojong MP, Alamsyah Z, Sibhatu KT** (2023) Oil palm expansion, food security and diets: Comparative Evidence from Cameroon and Indonesia; Journal of Cleaner Production 418: 138085 *https://www.sciencedirect.com/science/article/pii/S0959652623022436*
B14	**Teklemariam DM, Gailing O, Siregar IZ, Amandita FY, Moura CCM** (2023) Integrative taxonomy using the plant core DNA barcodes in Sumatra's Burseraceae; Ecology and Evolution 13: e9935 *https://onlinelibrary.wiley.com/doi/10.1002/ece3.9935*
B08, A01	**Tsyganov A, Malysheva E, Mazei YA, Hapsari A, Behling H, Sabiham S, Biagioni S, Krashevska V** (2022) Species- and Trait-Based Reconstructions of the Hydrological Regime in a Tropical Peatland (Central Sumatra, Indonesia) during the Holocene Using Testate Amoebae; Diversity 14; 1058 *https://www.mdpi.com/1424-2818/14/12/1058*
B11, A01, A02, B02, B06, B08, B07, B09, B14, Z02, INF	**Zemp DC, Guerrero-Ramirez N, Brambach F, Darras K, Grass I, Potapov A, Röll A, Arimond I, Ballauff J, Behling H, Berkelmann D, Biagioni S, Buchori D, Craven D, Daniel R, Gailing O, Ellsäßer F, Fardiansah R, Hennings N, Irawan B, Khokthong W, Krashevska V, Krause A, Kückes J, Li K, Lorenz H, Maraun M, Merk MS, Moura CCM, Mulyani YA, Paterno GB, Pebrianti HD, Polle A, Prameswari DA, Sachsenmaier L, Scheu S, Schneider D, Setiajiati F, Setyaningsih CA, Sundawati L, Tscharntke T, Wollni M, Hölscher D, Kreft H** (2023) Tree islands enhance biodiversity and functioning in oil palm landscapes; Nature 618: 316–321 *https://www.nature.com/articles/s41586-023-06086-5*
B08	**Zhou Z, Krashevska V, Widyastuti R, Scheu S, Potapov A** (2022) Tropical land use alters functional diversity of soil food webs and leads to monopolization of the detrital energy channel; eLife 11:e75428 *https://elifesciences.org/articles/75428*
B08	**Zhou Z, Lu J-Z, Preiser J, Widyastuti R, Scheu S, Potapov A** (2023) Plant roots fuel tropical soil animal communities; Ecology Letters 26: 742-753 *https://onlinelibrary.wiley.com/doi/10.1111/ele.14191*

2. REVIEWS published since June 2022

C02, C06, C08	**Petri H, Hendrawan D, Bähr T, Asnawi R, Musshoff O, Wollni M, Faust H** (2023) Replanting challenges among Indonesian oil palm smallholders - a narrative review; Environment, Development and Sustainability *https://link.springer.com/article/10.1007/s10668-023-03527-z*

3. OTHER PUBLICATIONS published since June 2022

Z02	**Hidayat P, Siddikah F, Kasmiatun, Noerdjito WA, Amrulloh R, Hiola MS, Najmi L, Nazarreta R, Scheu S, Buchori D, Drescher J** (2022) Guidebook of beetles and weevils of Jambi, Sumatra, Indonesia; e-Publishing Penerbit BRIN, ISBN-13 (15) 978-623-7425-71-7 *https://penerbit.brin.go.id/press/catalog/book/321*

4. EFForTS DISCUSSION PAPER SERIES published since June 2022

C02	**Thi NP, Hein J, Kunz Y, Mardiana R, Faust H** ( ) Land use change and governance in Jambi, Indonesia - synthesis of qualitative social sciences results; EFForTS discussion paper series 37

5. SUBMITTED PAPERS

A02, A03, Z02	**Bulusu M, Ellsäßer F, Stiegler C, Ahongshangbam J, Marques I, Hendrayanto, Röll A, Hölscher D** (2023) UAV-based thermography reveals spatial and temporal variability of evapotranspiration from a tropical rainforest;
A05	**Chen G, Veldkamp E, Damris M, Irawan B, Tjoa A, Corre MD** (2023) Large contribution of soil N2O emission to the global warming potential of a large-scale oil palm plantation despite changing from conventional to reduced management practices;
C12	**Knoke T, Hanley N, Paul C** (2023) Economic benefits of reduced deforestation are offset by excess deforestation – a counterfactual simulation;
A01	**Nguyen CH, Hapsari KA, Saad A, Sabiham S, Behling H** (2023) Late Holocene riparian vegetation dynamics, environmental changes, and human impact in the Harapan forest of Sumatra, Indonesia; Frontiers in Ecology and Evolution
B08, B09, Z02	**Potapov AM, Drescher J, Darras K, Wenzel A, Nazarreta R, Kasmiatun, Mawan A, Pollierer MM, Widyastuti R, Buchori D, Hidayat P, Turner E, Grass I, Westphal C, Tscharntke T, Scheu S** (2023) Rainforest transformation reallocates energy fluxes from above- to belowground food webs;
C07	**Sibhatu KT, Tabe-Ojong MP, Siregar H** (2023) Sustainable Intensification Using Natural Land Management Practices in Smallholder Oil Palm Production;
C07	**Tabe-Ojong MP, Geffersa AG, Sibhatu KT** (2023) Effect of Producer Organizations on Sustainable Intensification of Oil Palm Production and Yields in the Congo Forest Basin;

V. Early Career Support: Education and Promotion of Junior Researchers

1. Postdoctoral researchers

Since the start of the project in 2012, **49 postdoctoral researchers** conducted their research work in EFForTS. 36 were/are funded by DFG and 13 by other grants. In Phase 3 (2020-2023), each of the Postdocs in the project is integrated in synthesis activities that receive particular attention from EFForTS PIs as well as Group Speakers and Foci speakers to the benefit of the career of postdoctoral researchers functioning as first authors of these papers.

2. Doctoral researchers

About 100 doctoral researchers participate(d) in EFForTS, thereof 42 researchers with external scholarships or university (UGoe) funding. To date, 73 doctoral researchers have completed their dissertations at the University of Göttingen, including 23 PhD students from Indonesia.
At IPB University in Bogor, 10 doctoral researchers concluded their work.

3. Master theses

EFForTS also supports the higher education of master students. Since 2012, 107 master students completed their studies at Göttingen and 46 master students at our partner universities in Indonesia.

DISSERTATIONS

Table 10. Newly completed dissertations of Phase 3 – University of Göttingen. Update since newsletter no. 8, July 2022.

Scientific Project	Name	Type of funding	Title of thesis
A05	**Guantao Chen**	Chinese Scholarship Council (CSC)	Soil greenhouse gas fluxes and nutrient leaching losses in a large-scale oil palm plantation: conventional versus reduced fertilization rates and weed control (June 2023)
Z02	**Daniel Ramos Gutierrez**	KAAD & Institute Scheu	Diversity, phylogeny and trophic ecology of arboreal spider (Araneae) assemblages along a transformation gradient from lowland rainforest to oil palm plantations in Jambi Province, Sumatra, Indonesia (*December 2022*))

Table 11. Newly started dissertations of Phase 3 – University of Göttingen. Update since newsletter no. 8, July 2022

Scientific Project	Name	Type of funding	Title of thesis
A02	**Thorge Wintz**	Institute Hölscher	Evapotranspiration from tropical mosaic landscapes (since September 2022)
Z02	**Muhammad Naufal Rizqulloh**	Institute Scheu & DFG	Diversity, Phylogeny and Trophic Ecology of Arboreal and Terrestrial Ant Communities along a Lowland Rainforest Transformation Gradient (since February 2023)
Z02	**Azru Azhar**	Institute Scheu & DFG	Diversity and trophic ecology of arboreal Braconids wasp (Hymenoptera) along a lowland rainforest transformation gradient in Jambi, Sumatra, Indonesia (since October 2022)

MASTER THESES

Table 12. Master theses at the University of Göttingen – newly started or completed since July 2022.

Completed		
A03	**Bayu Budi Hanggara**	Analysis of the dynamics of land-use gradient intensity on the greenhouse gas emissions, surface energy balance, and water efficiency in Southeast Asian forest and plantation systems (January 2023)
B10	**Rebeca Groninga**	Modelling the effect of landscape structure on biological pest control in rainforest transformation systems (December 2022)
B11/ Z02	**Antonia Fels**	Butterfly diversity in Sumatra: Effects of land-use change in smallholder systems and biodiversity enrichment in industrial oil palm plantations (December 2023)
B11	**Sonja Rebecca Heiliger**	Diversity of mammals in a biodiversity enriched oil palm plantation (February 2023)
B11	**Tatsuro Kikuchi**	Development of vegetation structural complexity in an enrichment oil palm plantation (Sumatra, Indonesia) (May 2023)
B11	**Maria Alejandra Moraless**	Herbivory in biodiversity-enriched oil palm plantations in Jambi, Sumatra, Indonesia (March 2023)
C07	**Usda Kristina Tassariya**	Women's Participation in Oil Palm Production and Effects on Household Income (Janary 2023)
C12	**Desalegn Yadeta Wedajo**	A review of collaborative and participatory modelling approaches in the context of land-use modelling approaches to inform agricultural and forest management (July 2023)
Z02	**Valentine Laurent**	Shift in diversity and trophic positions of beetle (Coleoptera) families after rainforest conversion to monoculture cash crops in Jambi, Sumatra (September 2022)
Z02	**Radit Sawaskorn**	Changes in diversity and community assembly of canopy leaf beetles (Coleoptera: Chrysomelidae) after rainforest conversion to rubber and oil palm plantations (September 2022)
Z02	**Kristin Cavanaugh**	The effects of tropical rainforest transformation on the trophic structure of canopy Diptera, Formicidae, and parasitoid wasps (March 2023)
Newly started		
A01	**Irene Polgar**	Composition of pollen collected by stingless bee Tetragonula laeviceps in different land-use systems (March 2023)
B06	**Sarah Kabache**	The effect of tropical land-use changes on vegetation structure in Sumatra, as measured with mobile LIDAR (June 2022)
B09	**Angelina Stockinger**	Predation services by bats, birds and ants in tree-enriched oil palm plantations (January 2023)
B09	**Laura Stoerzer**	Trade-offs and synergies between predator diversity and crop yield in treeenriched oil palm plantations (January 2023)
B10, C08	**Niamh Halmschlag**	Developing a conceptual model for integrating payments for ecosystem services into an agent-based land use change model of tropical transformation systems (February 2023)
B10	**Dejana Golic**	The effect of drought on transpiration and productivity of oil palm and rubber plantations - A simulation modelling approach (March 2023)
B11	**Pralhad Khadka**	Plant ecological strategies of natural regenerating species in tree islands in Sumatra, Indonesia (May 2023)
B11	**Thuy Quynh Kieu**	Effects of above- and belowground tree species on soil water infiltration in an oil palm landscape (Sumatra, Indonesia) (June 2023)
C02	**Maike Buckemüller**	Oil palm cultivation and intra-household gender roles in rural Jambi (January 2023)
C02	**Franziska Halbach**	Sustainability perceptions and intra-household capabilities for transformation in rural Jambi (January 2023)

Table 13. Master theses at the IPB University – newly started or completed since July 2022.

Completed		
Taniy June, A03	**Siti Nadia Nurul Azizah**	Biogeophysical impacts of land use change in Jambi Province on lifting condentation level and rainfall (2022)
Newly started		
Purnama Hidayat, Z02	**Endah Hari Utami**	Diversity of beetles (Coleoptera) at Harapan rainforest, Jambi
Damayanti Buchori, Z02	**Nadila Dwi Lestari**	Diversity of Hymenoptera parasitica on canopy at Bukit Duabelas National Park and Harapan rainforest, Jambi
Damayanti Buchori, Z02	**Rizky Desriana**	Richness and composition of arboreal ants in different landuse type at Harapan rainforest and Bukit Duabelas National Park, Jambi
Damayanti Buchori, Z02	**Ulfa Ulinuha**	Diversity of Diptera canopy across landuse systems in Bukit Duabelas National Park and Harapan rainforest, Jambi
Triadiati, B04	**Melda Syam Tonra**	Competition and resource sharing on roots in enriched oil palm plantations
Triadiati, B04	**Susi Susilawati**	Effect of land-use change Intensification on root strategy in utilizing resources

Table 14. Master theses at UNJA – newly started or completed since July 2022.

Completed		
Ir. Rosyani, C02	**Nurbaya Hakim**	Enabling Factors Effect the Implementation of Oil Palm Replanting In Tanjung Jabung Barat District Jambi Province-Sumatera-Indonesia (2022)
TNBD, Z01	**Asri Buliyansih**	Status of Sustainability of Food Consumption Patterns of the Internal Child Tribe (SAD) at Resort II.E Air Hitam I Bukit Duabelas National Park (2023)
PT Reki, Z02	**Ardiansyah**	Legal Protection for Ecosystem Restoration Concession Forest Areas (Case Study: Concession Areas of PT Restorasi Ecosystem Indonesia) (2023)
Newly started		
Ir. Rosyani, C02	**Victor Marpaung**	Smallholder's Perception Of Treatment Of "Plot Scale" On Oil Palm Plantation Of Rural Communities In Jambi Province

Table 15. Master theses at UNTAD – newly started or completed since July 2022.

Newly started		
Henry Barus, C02	**Nurhidayanti Zahlin**	Identification and Analysis of Arbuscular Mycorrhizal Diversity in Different Soils Using the Polymerace Chain Reaction (PCR) Technique
Henry Barus, C02	**Zulfadli**	Identification and utilization of arbuscular mycorrhizae as an agent for controlling *Fusarium* wilt in shallots

VI. Central Meetings of *EFForTS*: Meetings, Workshops, Retreats, Colloquia, Trainings, Seminar Series and Social Gatherings

Central meetings of the CRC play an essential role to promote scientific exchange between the researchers, to foster the international collaboration and networking with the partners in Indonesia, and to provide a fruitful research environment for our young academics.

Table 16. Central / group meetings of EFForTS in 2022 & 2023: Overall Project Team, Research Groups, Boards, Counterparts and Stakeholders.

Event / Venue Date	Topic
Annual Retreat 3–5 July, 2022	- The annual retreat took place in Volpriehausen from July 3 to 5, 2022. After the pandemic, this was the first workshop that met in presence. 130 participants from Germany and Indonesia joined the event.  **Picture 61.** Annual retreat in Volpriehausen from July 3 to 5, 2022.

Boards Göttingen & Indonesia 5 Jul 2022	- The Joint Management Board met on Jul 5, 2022 in Volpriehausen. Topics: Extension of MoA beyond Phase 3, data management & research infrastructure (storage and handover, and collaboration after Phase 3.
31 Mar 2023	MEETING OF JMB MEMBERS WITH BRIN REPRESENTATIVES - Dr. Aiyen Tjoa (Vice Rector of Collaboration Affairs, UNTAD) and Prof. Iskandar Z. Siregar (Vice Rector for Global Network Collaboration and Alumni Affairs, IPB University) met Prof. L.T. Handoko (Chairman of BRIN) and Prof. Agus Haryono (Deputy of Facilitation of Research and Innovation of BRIN) to discuss and exchange: A) (Technical) problems concerning the ethical clearance and research permit application B) Handover of data after project end of EFForTS (setting up a transfer agreement).  **Picture 62.** Meeting of JMB members with BRIN representatives on March 31, 2023. From left to right: Prof. Aguss Haryono, Prof. Iskandar Z Siregar, Prof. L.T. Handoko, Dr. Aiyen Tjoa, Majidu (Office assistant of the vice rector, IPB University).

UGoe

26 Oct 2023 –
8 Feb 2024

PUBLIC LECTURE SERIES PAULINERKIRCHE WS 2023/24: UMWANDLUNG TROPISCHER REGENWÄLDER: SOZIALE UND ÖKOLOGISCHE FOLGEN UND PERSPEKTIVE

- The following questions will be addressed: What are the ecological and socio-economic effects of this transformation? Who benefits and who loses? How large is the ecological footprint we leave behind in the tropics? How can negative effects be offset and unwanted trends reversed?

- Keynote speakers are:
  - *Stefan Scheu*: Transformation tropischer Regenwälder in Sumatra, Indonesien: Einblicke in ein integriertes Forschungsprogramm und Perspektiven für ober- und unterirdische Nahrungsnetze
  - *Matin Qaim*, ZEF Bonn: Wie nachhaltig ist eigentlich Palmöl?
  - *Daniel Murdiyarso*, World Agroforestry Center: After all the forests went up in smoke would your chocolate taste the same?
  - *Teja Tscharntke*, UGoe: Hohe Biodiversität und hoher Ertrag - kein Widerspruch in Agroforstsystemen
  - *Dirk Hölscher*, UGoe: Landnutzung und das Potential von Agroforsten in Madagaskar
  - *James Herrera*, Duke Lemur Center: Biocultural approach to landscape restoration in Madagascar
  - *Rachel D. Garrett*, Cambridge: From zero-deforestation policies to bio-economic value chains in the tropics
  - *Edzo Veldkamp*, UGoe: Können wir die Bewirtschaftung großer Ölpalmenplantagen so verbessern, dass sie weniger umweltschädlich ist?
  - *Heiko Faust*, UGoe: Globale Umwelt-Governance und lokale Umwelt-Gerechtigkeit in Sumatra, Indonesien
  - *Vojtěch Novotný*, Czech Academy of Sciences: Papua New Guinea rainforests and their indigenous peoples: history of a complicated relationship
  - *Clara Zemp*, Neuchatel: Bauminseln in einem Meer aus Ölpalmen
  - *Meike Wollni*, UGoe: Wege zu mehr Nachhaltigkeit im Ölpalmenanbau
  - *Aiyen Tjoa*, UNTAD: International research collaboration on changing rainforest landscapes in Indonesia
  - *Katrin Böhning-Gaese*, Senckenberg Biodiversität und Klima Forschungszentrum: Biodiversität und Mensch im Anthropozän

Figure 64a,b.

Table 17. Workshops and trainings of EFForTS in 2022 and 2023.

<table>
<tr><th>Venue / Date</th><th>Event</th></tr>
<tr><td>IPB University
3-5 Aug 2022

C08 –
Immanuel Manurung</td><td>A PARTICIPATORY RURAL APPRAISAL – TRAINING OF TRAINER (PRA-TOT)
- This training was conducted by PT Adil Organic Indonesia for 21 researchers and field assistants from IPB University, UNJA & UNTAD who apply or will apply participatory methods and bottom-up approaches with rural communities. The approach aims to incorporate the knowledge and opinions of rural people in the planning and management of development projects and programs.
- Ibu Leti Sundawati, IPB University and counterpart of B11 and PR opened the training workshop.


Picture 63. Participants of the PRA-TOT training workshop.


Picture 64. Handing over of certificates.</td></tr>
<tr><td>PT Humusindo &
IPB University
4 + 26 Aug 2022

Z02
Jochen Drescher
& Naufal Urfi</td><td>E-CAPTURE
- Aim: a) To give a general lecture on the identification and diversity of insects (field sampling and identification), b) To introduce to the platform iNaturalist (https://www.inaturalist.org/) with the goal to advance the citizen science movement and community awareness of local biodiversity, and c) To promote further exploration of the local environment which could be accessed by people in other parts of the world
- On Aug 24 about20 field assistants of EFForTS participated, on August 26 about 39 students and lecturers from IPB University and UNJA.


Picture 65. Training of 39 students and lecturers from IPB University and UNJA.

Picture 66. Training of 20 field assistants at PT Humusindo.</td></tr>
</table>

UNJA
23 + 24 Sep 2022

Z02 –
Purnama Hidayat,
Damayanti Buchori,
Naufal Rizqulloh,
Rizky Nazarreta,
Ratna Rubiana

THE IDENTIFICATION OF ANTS

- Aim: To improve the capacity building of Indonesian researchers and entomologist. Further, to share knowledge for PEI members, research assistants, and the general public concerning the taxonomy of ants.
- Theoretical background was provided on 23 September 2022 for students and the interested public, followed by a practical course work on 24 September 2022 in the EFForTS Office for students and lecturers of UNJA.

Picture 67. Practical course work on Sep 26, 2022 for students and lecturers of UNJA.

Figure 65. Workshop "The identification of ants

PT Humusindo
12+13 Oct 2022

C08 –
Immanuel Manurung

EXCURSION AND WORKSHOP OF THE SUSTAINABLE VILLAGE PROJECT

- Villagers of Pematang Kabau were invited to visit and learn about the enrichment experiment of EFForTS-BEE and an intercropping site of oil palm with cacao & fruit trees near Bungku village.

Picture 68. Villagers from Pematnag Kabau visit EFForTS-BEE plots.

IPB University
10–15 Oct 2022

Z02 –
Purnama Hidayat,
Damayanti Buchori,
Naufal Urfi

+

Stephanie L. Loria
(Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity, Berlin)

AN INTRODUCTORY WORKSHOP TO ARACHNID BIODIVERSITY AND ARTISTIC SPIDER'S ILLUSTRATION

- Aim: To train students of IPB University with regard to biodiversity and identification of spiders and scorpions. Practical course work took place in Gunung Walat-Bogor. Participants also enjoyed an exhibition of artistic spiders' illustration.

Picture 69. Field trip to Gunung Walat, workshop training on arachnid biodiversity and artistic spider's illustration in 2022.

Picture 70. Artwork (Salinan Curculionidae) from Bonauli Pakpahan (Z02 assistant) presented at the Joint Annual Meeting (On-Demand program), 13-16 November 2022': "Art-science interphase: Transdisciplinary of insect science in Java's shadow puppets, Indonesia" biodiversity and artistic spider's illustration in 2022.

UNJA
10–21 Oct 2022

A01 –
Svea Lina Jahnk,
Chung Nguyen
& Asmadi Saad

INTRODUCTION TO PALYNOLOGY AND PALEOECOLOGY

- The two-week training workshop was offered for master and bachelor students at UNJA to learn basic skills of paleoecological research. Two field trips were carried out in the first week to a) Muaro Jambi Temple Complex to study human influence on the landscape and past land use, and b) to the Bram Itam peat protection area (BIPA) to study paleoenvironmental signals of past sea level changes and peat development. At both sites, common paleoecological coring methods were practiced.

Picture 71. Participants of the paleoecology workshop.

- The class and lab studies included an introduction to basic sampling and laboratory methods as well as exercises in data analysis and interpretation. Furthermore, laboratory methods were taught at the paleoenvironmental laboratory of Jambi University comprising the preparation of palynological and charcoal samples.

Picture 72.
Field visit to Bram Itam peat protection area

Picture 73.
Pollen counting.

Pematang Kabau & UNJA
19 Oct 2022

C08 – Immanuel Manurung

- In an interactive one-day workshop on "PARTICIPATORY ACTION RESEARCH FOR SUSTAINABLE TRANSFORMATION IN PEMATANG KABAU VILLAGE" forestry students of UNJA explored general and participatory research methods.

Metz, France
Nov 2022

B09 –
Arne Wenzel
B10 –
Sebastian Fiedler &
Kerstin Wiegand
B11 –
Gustavo Paterno

RAINFOREST TRANSFORMATION INTO AGRICULTURAL LANDS: CURRENT AND FUTURE CHALLENGES – Symposium at the joint conference of the German, Austrian, Swiss, French and the European Ecological Societies

- Talks from EFForTS and other international research projects related to sustainable rainforest management and synergies across project findings and challenges.

Picture 74. Gustavo Paterno presents his research at the symposium "Rainforest transformation into agricultural lands: current and future challenges" in Metz, France.

UNJA & PTPN 6
8 Dec 2022

Z01 –
Aiyen Tjoa

- Prof. Nizam – Director of Diktiristek-Kemendikbudristek – visited the climate tower of EFForTS at PTPN 6. He also gave a guest lecture for students and staff at UNJA.

Picture 75. Visit of Prof. Nizam of climate tower at PTPN 6. From left to right: Melda, Susi, Galip, Eka, Bayu, Ardian, Basri, driver of Unja, Thorge, Aiyen, Pak Nizam, Pak Rayandra, Pak Yusrizal, Pak Kamid, and Shara.

Picture 76. Guest lecture of Prof. Nizam at UNJA (Form left to right: (Prof. Rayandra, Prof. Nizam, Prof. Sutrisno, Dr. Aiyen Tjoa).

UGoe
13 + 14 Feb 2023

B09 –
Arne Wenzel
+ Focus 3

LANDSCAPE ASSESSMENT: UPSCALING WORKSHOP (HYBRID):

- The objective of this workshop was to learn about analytical tools that enable the upscaling of local data, measured at the plot scale, to a larger landscape or even regional scale. We had the privilege of hosting several esteemed speakers who shared their expertise with our students, PhDs and postdocs.
- The workshop started with a presentation by Dr. Michael Schlund, who provided an overview of the remote sensing data collected during the third phase of the EFForTS project. He highlighted the potential of this data for our research and its use for upscaling analyses. Following that, Prof. Dr. Florian Hartig delivered a general introduction to Machine Learning methods in Ecology. He emphasized the immense potential of these methods while also discussing their inherent risks and limitations. To conclude the first day, Dr. Brian May from the GEDI project presented on spatial Bayesian statistics, focusing on the techniques for interpolating data in space by leveraging spatial correlation patterns. On the second day, we had a hands-on workshop by Prof. Dr. Damaris Zurell, focusing on the fundamentals of species distribution modelling in R.
- Overall, the workshop provided a valuable platform for learning and exchanging ideas on upscaling local data to broader scales, equipping us with practical tools for our research.

UGoe
22 Feb 2023

B10 –
Sebastian Fiedler

EFFORTS-ABM SYNTHESIS WORKSHOP (HYBRID):

- Aim: To assess the effect of landscape composition, environmentally friendly management (BEE, OPMX) as well as payments for ecosystem services on trade-offs and synergies among socio-economic and ecological functions.
- General discussion about ideas: e.g. landscape fragmentation and price scenarios on multifunctionality, individual functions, and trade-offs among them at different temporal and spatial scales?
- Scales, multifunctionality and trade-offs: Spatial and temporal scale(s), How to measure multifunctionality and trade-offs?

Pematang Kabau
12 Mar 2023

C08 –
Immanuel
Manurung

CAPACITY BUILDING WORKSHOP - PROJECT PROPOSAL WRITING

- The aim of the workshop was to build up capacity and to transfer knowledge regarding fund raising / project proposals (techniques, tools, strategies) for representatives of farmer groups, women farmer groups, cooperatives, village administrators, and fisheries communities in the village of Pematang Kabau.
- Syahru Ramadhan was invited as professional local trainer from Jambi City to share his experience in successfully assisting many local institutions to write proposals for securing funding from public and private organizations in Jambi Province


Pictures 77 and 78. Participants of the workshop "Project proposal writing"

IPB University
March 2023

C11 –
Anette Ruml
& Jann Lay

- In March 2023, a collaborative workshop was arranged with IPB University in Bogor. The purpose of this workshop was to share and deliberate on the combined research efforts within the CRC project and the BMZ funded research project titled *"Large-Scale Land Acquisitions, Rural Change, and Social Conflict."* This event welcomed participation from fellow researchers, as well as master's and doctoral students at the IPB. Following the workshop, we were invited to visit the IPB model farm alongside local researchers.

Picture 79. Collaborative workshop "Large-Scale Land Acquisitions, Rural Change, and Social Conflict".

IPB University
March 2023

C11 –
Anette Ruml
& Jann Lay

Pictures 80. Collaborative workshop "Large-Scale Land Acquisitions, Rural Change, and Social Conflict".

Picture 81. Visit of IPB model farm.

UNJA
3 Apr 2023

Z01 –
Aiyen Tjoa

- Aiyen organized a meeting for 42 field assistants and counterparts from UNJA to discuss the closing of the EFForTS the end of 2023.

Picture 82. Meeting of field assistants and counterparts.

UGoe
3 Apr 2023

B09 –
Arne Wenzel

UPSCALE ENVIRONMENTAL FLUXES/DATA

- Members of the group of Martin Jung from Max Planck Institute Jena presented how they upscale environmental fluxes and introduced to FluxCom.

IPB University
4 May 2023

B11 –
Gustavo Paterno

- Gustavo conducted a one-day workshop for students from IPB University:

LEARNING FROM PHYLOGENETIC TREES: AN INTRODUCTION TO PHYLOGENETIC METHODS FOR COMMUNITY ECOLOGY.

Picture 83. Phylogenetic workshop for students from IPB University.

UNJA & Berkah Sawi Utama Company
31 May – 3 Jun 2023

B06 –
field team

IDENTIFICATION OF WEEDS IN OIL PALM PLANTATIONS

- The B06 field team carried out a 4-day training workshop for 22 participants from the company PT BSU from 31 May to 3 June. Participants learned to recognized important plant families and agricultural weeds, including alien plants and practiced plant collection and preparation of herbarium specimens.

Pictures 84 and 85. Workshop for staff from PT BSU.

IPB University, UNJA, UB
28 Apr, 12 May, 23 Jun 2023

1 + 4 + 30 May 2023

INF –
Lisa Marques & Aytaj Badirova

ONLINE STATISTICAL TRAINING COURSES & INTRODUCTION TO DATAVERSE:

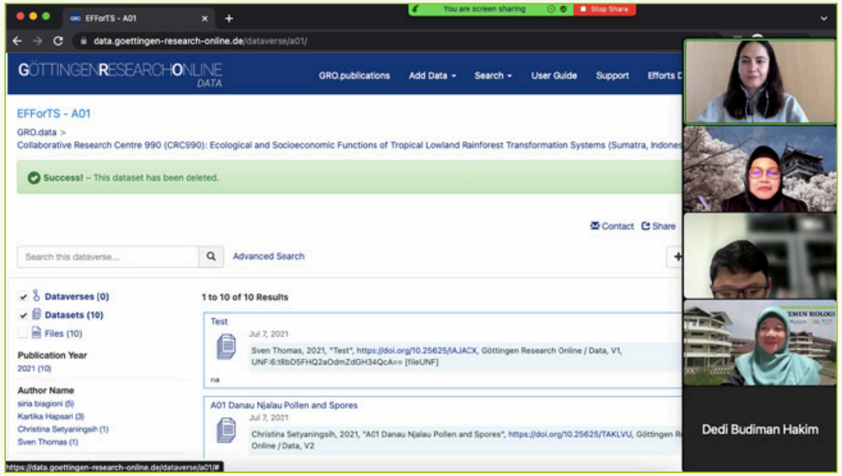
- The trainings were conducted for counterparts, research assistants and lecturers of our partner institutions

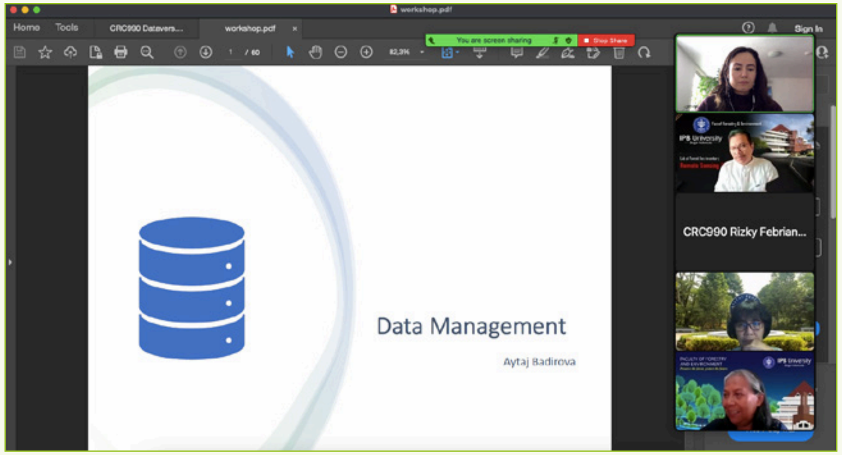
INTRODUCTION TO STATISTICAL ANALYSIS AND APPLICATIONS IN R (Isa Marques)

- LM, GLM; GLMM (17 participants)
- Basic R (20 participants)
- PCA (16 participants)

DATA MANAGEMENT AND DATAVERSE (Aytaj Badirova) (41 PARTICIPANTS)

- General aspects of data management, particularly in research and academia,
- The primary steps of data management life cycles,
- Data storage and preservation strategies,
- The significance of metadata,
- Legal and ethical perspectives of data collecting and processing,
- Theoretical and practical explanation of the data management tool Dataverse.





Pictures 86 and 87. Data management and Dataverse workshops

UNJA
5-7 Oct 2023

PR –
Finn Matthiesen

MAKING EFFORTS EDUCATION AVAILABLE FOR INDONESIA AND THE WORLD

- Expected are 25 participants (counterparts, lecturers, research assistants)
- Workshop agenda: validation of research results, experts reviews , improvement of educational modules, work session for open book chapters and dissemination strategies
- On October 7, a field trip is planned to the research sites *EFForTS-OPMX* and *EFForTS-BEE*

Table 18. Joint colloquium of Göttingen and Indonesian researchers in 2022 and 2023

IPB University 21 Oct 2022 **C08**	- Immanuel Manurung: *Exploring sustainable land use options in oil palm landscapes*
IPB University 4 Nov 2022 **A01**	- Svea Lina Jahnk & Chung Nguyen: *Introduction to palynology and paleoecology*
UGoe 11 Apr 2023 **Z02**	- Jochen Drescher: *Canopy Biodiversity Monitoring in EFForTS - past, present, future*
UGoe 2 May 2023 **A01**, **C07**	- Kibrom Sibhatu / C07: *Oil palm production and dietary change: Comparative evidence from Cameroon and Indonesia* - Nguyen Hoai Chung / A01: *Late Holocene riparian vegetation dynamics, environmental changes, and human impact in the Harapan forest of Sumatra, Indonesia* - Tiara Sayusti / IPB University: *Pollen diversity in honey revealed the foraging preference of the sympatric honey bee and stingless bee*
UGoe 6 Jun 2023 **A07**, **C01/C07/C08**	- Tobias Bähr / C08, Gabriela Carbajo / C01 & Jakob Latzko / C07: *Data collection in Costa Rica - early findings and learnings* - Ashehad Ali / A07: *Advantages of measuring leaf-gas exchange rates in large lowland areas of the Jambi Province*
UGoe 4 Jul 2023 **A07**, **B10**	- Sebastian Fiedler / B10: *Landscape structure effects on trade-offs among ecological and socio-economic functions at different temporal and spatial scales* - Ashehad Ali / A07: *Modeling biogeochemical cycles of forests, oil palm and rubber plantations for the lowland areas of the Jambi Province*

IPB University 5 May 2023 **B11**	IPB UNIVERSITY – Center for Transdisciplinary and Sustainable Sciences (CTSS) – 15TH GRADUATE STUDENT SUSTAINABILITY SEMINAR - Gustavo Paterno: *Restoring multiple facets of biodiversity and ecosystem functioning in oil palm landscapes*
UNJA 20 May 2023 **B11**, UNJA	UNJA – FIELD LECTURE FOR FOREST STUDENTS - Gustavo Paterno, Hamzah, Rince Mutyunika, and Jenny Rumondang: *Open lecture on Agroforestry systems within oil palm plantations for 30 agroforestry students visiting EFForTS-BEE*  **Picture 88a,b.** Field lecture for UNJA students in EFForTS-BEE plots.
UNJA 22 May 2023 **B11**, UNJA	UNJA – OPEN LECTURE AT THE FACULTY OF AGRICULTURE - Gustavo Paterno, Bambang Irawan, Eva Achmad, and Maria Ulfaz: *Restoring multiple facets of biodiversity and ecosystem functioning in oil palm landscapes*

VII. Public Relation and Knowledge Transfer

1. Summer camp at UNJA
2. 5th Night of Science in Göttingen
3. Girls Day in Science, University of Göttingen

1. SUMMER CAMP AT UNJA

In 2020, Jambi University has implemented Merdeka Belajar dan Kampus Merdeka which can be translated as "Freedom to Learn and Independent Campus" with the aim to conducting lectures in the form of summer camps in the field.

The Center of Excellence of Biodiversity and Landuse Transformation Systems (CoE BLasTS, headed by Bambang Irawan) at UNJA held a summer camp in 2021 on the topic "Biodiversity and Land Use Change". The students should increase the understanding and knowledge on how to protect and enhance the ecological functions of land-use systems while improving economic and social welfare. At the same time they should increase empathy and social sensitivity by interacting among fellow participants and with the community (learning the social structures and economic activities of the community).
On October 27, 2022, fourteen students visited *EFForTS-OPMX* (Pic. 89b) and the climate tower at PTPN 6 (Pic. 89a) as well as *EFForTS-BEE* at PT Humusindo from November 5 to 6, 2022).


a)


b)

Pictures 89a,b. Summer camp activities at the climate tower of EFForTS at PTPN 6 (left, Basri – A03 explains the climate tower) and in an OPMX site (right)

2. 5TH NIGHT OF SCIENCE IN GÖTTINGEN

EFForTS participated in the 5th Night of Science at the University of Göttingen on July 9, 2022. The exhibition took place in the "Forum Wissen".
Ideas and people:

- **A02** – Svea Jahnk: Microscope and pollen slides from honey samples
- **B04** – Sasya Samhita: Demonstration of equipment used in field work (e. g. dendriometer) + "root game" (which root system belongs to which landuse)
- **B08** – Johannes Lux: Stereomicroscope with living animals and pictures
- **B09** – Arne Wenzel: Soundscapes from oil palm and rubber plantations + "dummy caterpillar game" (caterpillars with bite marks – find out who caused them)
- **B10** – Sebastian Fiedler, Julia Henzler, Amsalia Pasila, Christian Wievelhowe: Presentation of an educational model of EFForTS-ABM
- **B14** – Carina Moura / Diendra Hendrawan-**C06** / Jakob Latzko-**C07**/ Rahmi Ariani-**A07** / Gabriela Carbajo-**C01**: Tree visualizing EFForTS + memory game "Trees & Flowers".
  Göttingen's Science Night was a captivating event where members from both the B and C groups engaged in discussions about the effects of forest conversion. Citizens of all ages joined in to explore and predict biodiversity measurements found by our research teams in the four investigated land use systems.
- **Z02** – Jochen: Supermarket (products containing palm oil) + ant puzzles + EFForTS movie

Pictures 90a, b. B10 research team at the Night of Science in Göttingen 2022 presenting the educational version of EF-ForTS-ABM to the public.

Picture 91. Night of Science - Dialogue about forest conversion into different land use systems. use types. On the right, from left to right, Carina Moura, Dienda Hendrawan, Jacob Latzko, Gabriela Carbajo, and Rahmi Ariani showcasing a quiz based on the EFForTS scientific findings.

- **PR** – Susanne Bögeholz: Poster „Bildung für Gestaltung von Gesellschaft – Wissen aus EFForTS-Forschung für Indonesien und weltweit verfügbar machen".

3. GIRLS DAY IN SCIENCE, UNIVERSITY OF GÖTTINGEN – CARINA MOURA / **B14**

In April 2022 and April 2023, the Forest Genetics department's B14 subproject, along with colleagues, hosted visits from young students from Göttingen and Hannover.
These visits aimed to educate the students about biodiversity surveys utilizing molecular techniques such as DNA barcoding and genomic research in plants. The students were provided with the unique opportunity to conduct experiments in the laboratory and engage in discussions regarding DNA-based approaches for plant surveys employed by B14 – EFForTS.

Figure 66. Girl's day in science is an outreach opportunity to inspire young female students to discover potential career pathways.

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