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BIODIVERSITY
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IS ARTHROPOD BIODIVERSITY ON THE RAINFOREST FLOOR THREATENED BY RUBBER AND PALM-OIL PLANTATIONS?

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Tropical rainforests are a particularly threatened type of ecosystem because humans are converting rainforests into farmland. On Sumatra, the world's sixth largest island, most of the tropical rainforest that once covered the island has been turned into plantations for rubber trees and oil palms. Rubber and palm oil, the agricultural products produced from such plantations, are an important source of income for the local farmers. Unfortunately, replacing rainforests with plantations reduces the number of arthropods, like insects and spiders that would normally live in the rainforests. This can have negative effects on ecosystem functions that are normally carried out by these arthropods, such as the decomposition of dead organic matter or the control of crop pests. We went to Sumatra to find out what happens to communities of ground-living arthropods, a diverse and ubiquitous group of animals important for the functioning of ecosystems, when rainforest is turned into plantations.

INTRODUCTION

Tropical Rainforests Are Being Converted to Agricultural Plantations

Tropical rainforests are among the most biodiverse ecosystems on earth. This means that they are home to more species of plants, animals, fungi, bacteria, and other forms of life than most other ecosystems on our planet. At the same time, tropical rainforests are threatened by humans, as we continuously turn large areas of forest into agricultural plantations. On such plantations, people can grow food and other natural products for themselves or to sell to global markets in order to earn money to feed their families. Humans have been turning forests into fields for their crops and pastures for their livestock since about 10,000 years ago, but the number of humans on earth keeps increasing, while the amount of forest land worldwide grows smaller every day. We need to understand the consequences that the conversion of forests to farmland has on the communities of organisms living in the forests, because these organisms keep ecosystems working in a healthy way. With this knowledge, we can conserve the most important natural forest areas, design farmland that has less negative impact, and, at the very least, be prepared for the negative impacts of rainforest conversion that might be unavoidable in the future.

Threatened Indonesian Rainforests Are a Biodiversity Hotspot

BIODIVERSITY

The variability of life, typically measured at the ecosystem level, the species level or the genetic level. Biodiversity loss is a major threat to natural ecosystems and mankind.

Southeast Asia is a hotspot of **biodiversity**, which means there are large numbers of rare species. Southeast Asia is also an area in which these species are threatened by loss of their natural habitat. Indonesia lies at the heart of this biodiversity hotspot, which makes it an important area for the conservation of natural habitats and the species that live there (Figure 1A). Unfortunately, Indonesia's rainforests are threatened by high rates of deforestation [1], in which forests are removed and replaced by other types of ecosystems. Moreover, Indonesia is the world's biggest producer of palm oil, a vegetable oil that is commonly used to produce food (everything from bread to ice cream), soaps, and even fuel. Also, rubber-tree plantations producing natural latex are common in Indonesia. Both oil palms and rubber trees are typically planted in **monoculture** (single-species) plantations by farmers or large companies. Just like most other monocultures, rubber and oil-palm plantations differ a lot from the ecosystems that they have replaced.

MONOCULTURE

An agricultural practice of growing only one crop species in a given field at a time.

Biodiversity Loss Has Consequences for the Way Ecosystems Function

When rainforests are destroyed, many species cannot survive in these areas and can vanish completely. Every species plays its own specific

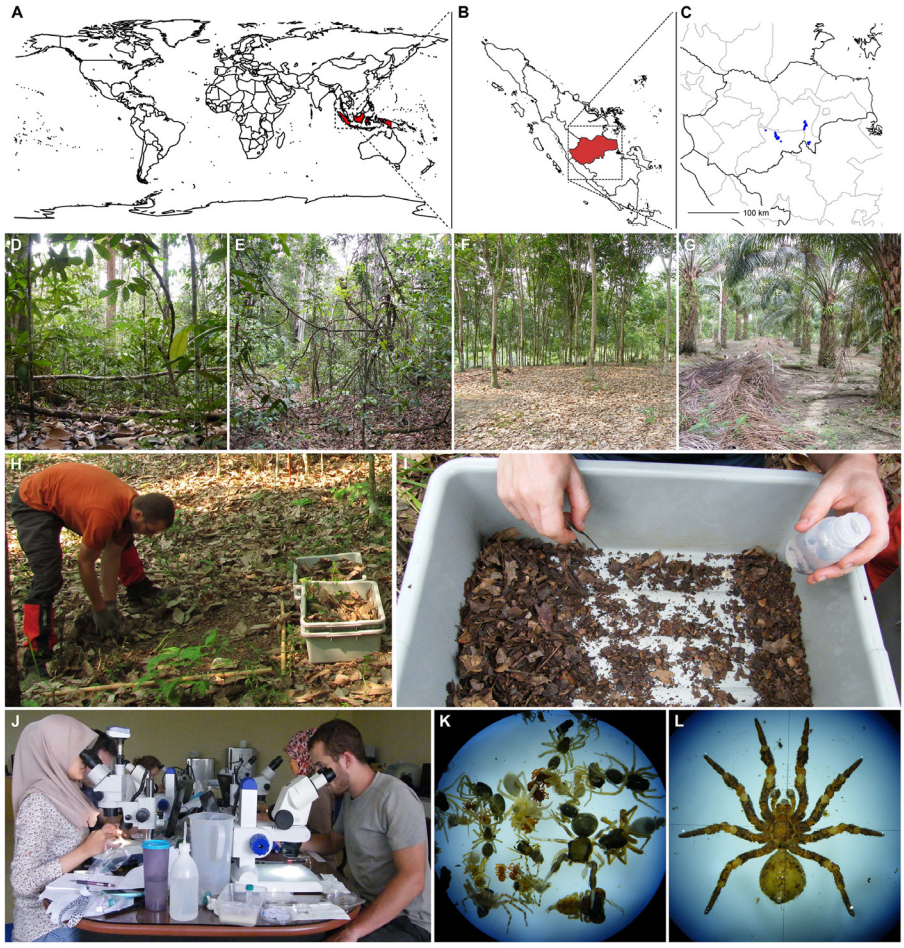

Figure 1

Figure 1

What did we do and how did we do it? Our study was conducted in Indonesia, in red **(A)**, on the island of Sumatra **(B)**, in the Jambi Province, in red. Blue dots in **(C)** show the distribution of research sites within two regions in the Jambi Province. Sampling took place across a total of 32 sites: 8 sites in each of 4 land-use systems: forest **(D)**, jungle rubber **(E)**, rubber plantations **(F)**, and oil-palm plantations **(G)**. On each research site, we collected the leaf litter on three square-meters of ground and dumped it onto a sieve **(H)**. Animal individuals were collected from the siftings by hand **(I)** and taken to the lab **(J)** where they were sorted into major groups, such as spiders **(K)**. They were then identified, counted and measured for their body length **(L)** to calculate individual body masses.

role within the ecosystem that it lives in. Every species consumes certain resources and is in turn eaten by other organisms higher up in the food chain. All of the organisms in an ecosystem carry out some work that keep ecosystems functioning–for example, by pollinating plants, helping dead organic matter (dead plants and animals) to decay, or by feeding on other animals. Scientists call these processes "ecosystem functions." We do not know all of the species on earth and we certainly do not know what all of them do. But we do know that if we lose species, we are in danger of losing the functions that they carry out. We, as ecologists, are interested in how different organisms interact and how these interactions affect the way that ecosystems function.

Can Arthropods Tell Us How Rainforest Loss Will Affect Tropical Ecosystems?

If you are interested in species loss in tropical forests, you will often hear about charismatic and well-known species, such as tigers and great apes, being endangered. While these beautiful and interesting species are important for their ecosystems, there are other organisms that often

escape the eye and that we know very little about. However, this does not mean that these less well-known species are less fascinating or important for the ecosystems they live in. **Arthropods** are one of the most diverse groups of organisms on our planet. Insects, spiders, centipedes, millipedes, and isopods are major groups of arthropods that you almost certainly see every day. You have probably noticed that there are many arthropods around of many different kinds. There are far more arthropods on our planet than primates and tigers combined. In fact, there is more total **biomass** (or weight) of arthropods than of mammals on earth [2]. Their wide distribution, diversity, and high biomass make arthropods important for the functioning of ecosystems, and thus we decided to focus on them for our study. Because we wanted to know what happens to arthropod communities when their natural habitat is turned into agricultural plantations, we went to Indonesia to study tropical arthropods in a rainforest that was being converted to rubber and oil-palm monocultures [3].

ARTHROPODS

A taxonomic group of animals defined by having an external skeleton, body segments and pairs of jointed appendages. Examples include spiders, insects (like beetles), and woodlice.

BIOMASS

Here, the total weight of all animals present in a given area, for example the total weight of all arthropods found on one square meter of rainforest ground.

WHAT DID WE DO AND HOW DID WE DO IT?

Studying the Effects of Changing Land Use for Ecosystems and Humans in Indonesia

In 2012, a large group of German and Indonesian researchers set out to study the consequences of changing **land use** on Sumatra, Indonesia. Within the project, small teams worked on different topics related to the overall question, "What happens to ecosystems and to the local people after tropical rainforests are turned into rubber and oil-palm plantations?" The first researchers that got to Sumatra (Figure 1B) chose and marked field sites where the teams could measure different organisms, soil characteristics, and local climate conditions. Across two different regions (Figure 1C), they selected 32 sites in rainforest, jungle rubber, rubber, and oil-palm plantations (Figures 1D–G). Jungle rubber is a special type of rubber plantation where rubber trees are planted inside the rainforest between the other trees. Rubber and oil-palm plantations are like cornfields, because they have only one species of plant that is maintained as a monoculture crop. In each of the two different regions, the researchers made sure that there were four repeated sites in each of the four types of land use. This replication (repeated measures of each system) assured that we could assess the average conditions for each system.

LAND USE

The management and modification of natural environments to provide certain goods or services. For example, oil-palm plantations are a managed agricultural environment providing palm oil.

Collecting Ground-Dwelling Arthropods on the Research Sites

Between October and November 2012, we sampled arthropods that live on the ground at the various sites, by collecting the decaying leaf litter from the forest floor and searching through it to find all the arthropods.

To do this, we built self-made sieves with a mesh size of about 2 cm. On every research site, we randomly selected three square-meter plots where we collected the leaf litter by scratching it off the ground with leather gloves (because you never know what potentially venomous animals you might find in tropical forests) and dumped it into the sieves (Figure 1H). As we shook the sieves, the smaller animals would then fall into the boxes below, where we could then hand-collect all the arthropods that we found (Figure 1I) and take them back to the laboratory.

Arthropod Samples Were Further Processed in the Laboratory

In the laboratory (Figure 1J), we first sorted the arthropods into major **taxonomic groups**, such as beetles, millipedes, or spiders (Figure 1K). We measured the body length of each individual and identified which species they were (Figure 1L). Many of these tropical arthropod species have never been found or described by scientists and have no name. Because of this, we had to try to distinguish different species by what they looked like, even though we did not know their official name. Then, we counted the number of individuals of each species on each of the sites and determined what **feeding guild** they belonged to: predators (feeding on other animals), herbivores (feeding on plant material), detritivores (feeding on dead animal or plant material) or omnivores (feeding on more than just one of these food resources). To determine arthropod biomass, we first estimated body masses based on the individual body lengths of all animals. Then, we added up these individual body masses to obtain total arthropod biomass, which is the total weight of living arthropods, for each of the different feeding guilds at each site.

TAXONOMIC GROUP

Taxonomy defines and names groups of organisms based on shared characteristics. Taxonomic groups can be defined at any level of taxonomic organization, for example the insect order Coleoptera—beetles.

FEEDING GUILD

A group of animals defined by what they eat, for example detritivores feeding on dead animal or plant material.

We Used Statistical Tests to Understand Changes in Arthropod Communities

After collecting 7,472 arthropod individuals, measuring lengths, calculating biomasses, counting numbers, and assessing species diversity, we used statistical tests to find out if there were overall differences in the arthropod communities in the leaf litter of the four different land-use systems. Additionally, we tested if the changes in diversity, individual density and biomass from forests to plantation ecosystems differed between the four feeding guilds.

WHAT HAPPENS TO ARTHROPODS ON THE FOREST FLOOR?

Oil-Palm Plantations Had Fewer Arthropods Than Did Forests

We found that oil-palm plantations contained fewer species, fewer individuals, and lower biomass of arthropods than the forest sites

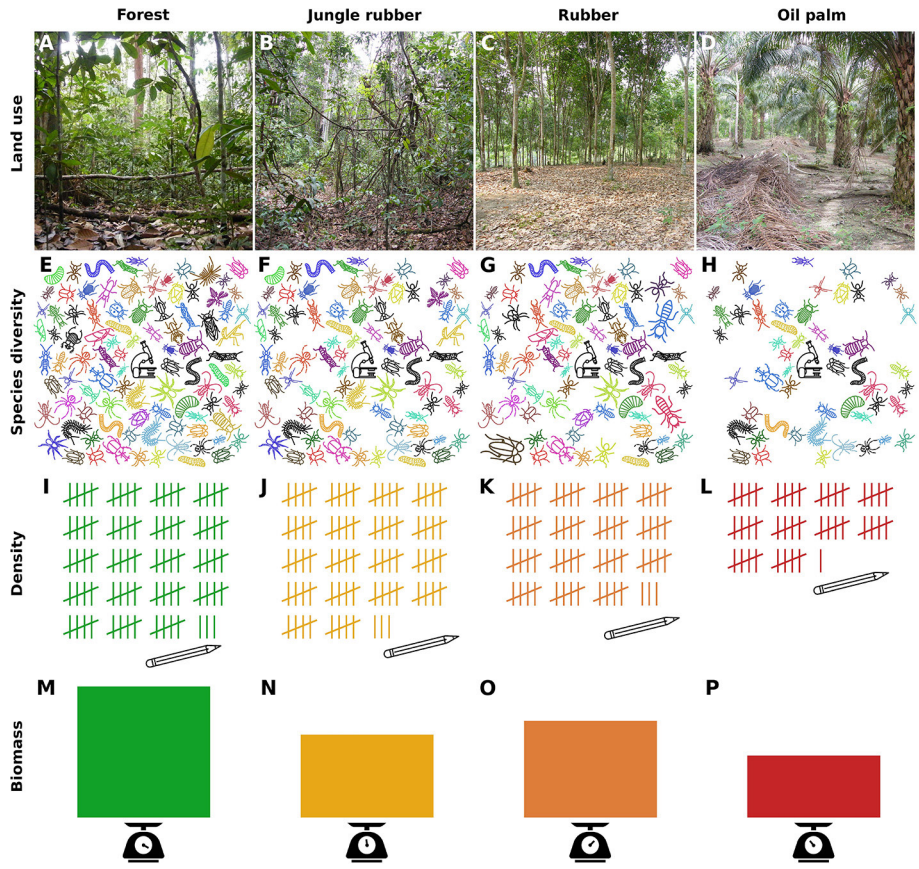

Figure 2

Figure 2

What did we find? Across the four land-use systems, forest **(A)**, jungle rubber **(B)**, rubber plantations **(C)**, and oil-palm plantations **(D)**, we analyzed litter arthropod species diversity on three square meters per site **(E–H)**, counted the number of arthropods per square-meter (density, **I–L**) and calculated arthropod biomass **(M–P)**. Results for the four land-use systems are presented in the columns below the pictures of those systems. We calculated the average values across the eight replicate sites per land-use system, which are shown by the number of species icons and tally marks. The biomass bars show average arthropod biomass per square meter and vary between 342 mg/m^2 in the forest and only 161 mg/m^2 in oil-palm plantations. In comparison with the forest sites, species diversity was reduced by 45%, individual density by 48%, and biomass by 52% in oil-palm plantations, respectively (Animal drawings by Yu luck, weighing scale altered after anbileru adaleru, pencil and tally marks altered after Juan Pablo Bravo, and microscope by Gregory Sujkowski from the Noun Project).

did (Figures 2A–D). In comparison with the forest sites, species diversity was reduced by 45% (Figures 2E–H), individual density by 48% (Figures 2I–L), and biomass by 52% (Figures 2M–P), respectively. This means that arthropod communities in the leaf litter were roughly halved in oil-palm plantations compared with rainforests. Now, what does this mean and why does it matter? Biodiversity loss has various consequences. In some cases, these consequences are more obvious, such as when a top predator—a species high up in the food chain that consumes other animals but is rarely ever consumed by others is lost. In this case, there can be cascading effects along the food chain because losing the top predator can result in an increase in its prey but a decrease in that prey's food, and so on. For example, losing wolves could lead to large herbivores, such as elk, growing in number because they are not being hunted, and feeding far more on the plants they like to eat, which are then heavily reduced. This changes the look of the ecosystem but also the functions that are carried out by the community. In most cases, the changes that happen following the loss of a few species might not be as dramatic. Still, other species that would normally feed on the lost ones will either need to switch food resources or leave their homes to find food elsewhere, so they do not starve. In our study, we found that the effects of land-use change from forest to oil palm differed between the four feeding guilds.

For species diversity and individual density, land-use change had the strongest negative effects on predators. As we explained in the example above, these changes in predator populations are concerning, because they can have cascading effects on other animal and plant species and disrupt the way that the whole ecosystem functions.

Biodiversity Loss Has Negative Consequences for the Way Ecosystems Function

Besides consequences for the animal and plant communities, there are other issues with biodiversity loss. For example, we know that in many cases higher biodiversity allows ecosystems to healthily perform several functions. Losing biodiversity might therefore lead to a loss in some of the services that people receive from ecosystems like clean air, clean water, and healthy soils. This is true for ecosystem functions, such as the growth of plants in grasslands, which humans rely on for producing food. Moreover, where there is higher biodiversity, ecosystems are able to perform more functions at the same time. This means that higher numbers of species in ecosystems can often provide more natural benefits to humans, which is one of the important reasons for protecting global biodiversity.

WHAT CAN WE DO TO PREVENT MORE SPECIES LOSS IN TROPICAL RAINFORESTS?

Our study has shown that arthropod species diversity, density, and biomass are strongly reduced in agricultural systems like oil-palm plantations. However, palm oil is a very important agricultural product in global food and fuel markets. Furthermore, oil palms produce more oil per unit area than other plants. This means that in order to switch from using palm oil to other vegetable oils, we would need to turn even larger areas of land into plantations. One way that we can prevent tropical species loss is to reduce our overall consumption of palm oil, by avoiding products that are made using it. This will help to convince larger companies that they should use less environmentally harmful products. Additionally, we can try to make palm-oil production more sustainable by reducing its negative impacts on nature. This can be done by using already cleared sites for new plantations, rather than cutting down existing forests. As another alternative, colleagues in our research project have established enrichment plantings in an oil-palm plantation [4]. They removed a few oil palms and planted small patches of local trees in the resulting gaps. The different tree species are used for timber production or to produce fruits and thus result in additional income for the plantation owner. At the same time, the tree patches attract and provide habitat for native bird and arthropod species within

the plantations and even lead to an increase in productivity of the oil-palm plantation. Such experiments and their results could be used to convince plantation owners to enrich their monocultures with additional plant species in order to make palm-oil production more sustainable and maintain higher levels of tropical biodiversity.

AUTHOR CONTRIBUTIONS

MJ wrote the first draft and created the figures and AB contributed to revising the manuscript to make it accessible for young minds.

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ORIGINAL SOURCE ARTICLE

Barnes, A. D., Jochum, M., Mumme, S., Haneda, N. F., Farajallah, A., Widarto, T. H., et al. 2014. Consequences of tropical land use for multitrophic biodiversity and ecosystem functioning. *Nat. Commun.* 5:5351. doi: 10.1038/ncomms6351

REFERENCES

1. Wilcove, D. S., Giam, X., Edwards, D. P., Fisher, B., and Koh, L. P. 2013. Navjot's nightmare revisited: logging, agriculture, and biodiversity in Southeast Asia. *Trends Ecol. Evol.* 28:531–40. doi: 10.1016/j.tree.2013.04.00
2. Bar-On, Y. M., Phillips, R., Milo, R., and Falkowski, P. G. 2018. *The Biomass Distribution on Earth*. Available online at: https://www.pnas.org/content/pnas/early/2018/05/15/1711842115.full.pdf
3. Barnes, A. D., Jochum, M., Mumme, S., Haneda, N. F., Farajallah, A., Widarto, T. H., et al. 2014. Consequences of tropical land use for multitrophic biodiversity and ecosystem functioning. *Nat. Commun.* 5:5351. doi: 10.1038/ncomms6351

4. Teuscher, M., Gérard, A., Brose, U., Buchori, D., Clough, Y., Ehbrecht, M., et al. 2016. Experimental biodiversity enrichment in oil-palm-dominated landscapes in Indonesia. *Front. Plant Sci.* 7:1538. doi: 10.3389/fpls.2016.01538

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YOUNG REVIEWER

LUANA, AGE: 15
I am a 15 years-old girl, who is passionate about animals, in particular, dogs. I want to become a Veterinarian Neurosurgeon, and help design prosthetic capable of interacting with the animals' nervous system. I love singing, being artistically creative, and biology.

AUTHORS

MALTE JOCHUM
I studied Biology because, as a teenager, I built a small pond in my parents' garden and realized that this subject would never cease to amaze me. As a community ecologist, I am very interested in how human activities affect the structure and functioning of plant and animal communities. My work has focused on aquatic and terrestrial ecosystems across temperate and tropical areas and mainly involves arthropods. When not at work, I like to explore nature with my daughter, do rock climbing, cycling, or canoeing and, more recently, I discovered an interest in beginner-level triathlon. *malte.jochum@idiv.de

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ANDREW D. BARNES

Since a very young age, I have been fascinated by the diversity and complexity of our natural world, especially that found in tropical rainforests. I work as a community ecologist, investigating how species interact with each other and how their interactions affect the way that ecosystems function. I am particularly interested in forest ecosystems and how humans impact the organisms that inhabit them, including everything from microbes to insects to birds. In my free time, I love doing outdoor activities like hiking and rock climbing, as well as traveling to other countries to explore new ecosystems and cultures.