Appendix 1. Detailed method description.

METHODOLOGY OF SOCIAL STUDY

The research stay in Indonesia comprised a period of three months in total. An initial two week one-to-one course of Bahasa Indonesia added up on prior autodidactic learning and provided the researcher with a good basic knowledge of the Indonesian language. This knowledge as well as several meetings with our Indonesian counterparts at the Agricultural University of Bogor and the University of Jambi helped to prepare the field research and to get important insights into the Indonesian culture. Except for two expert interviews in Bogor, all interview activities were conducted in Jambi province during a period of eight weeks from May to July 2013. All interviews were conducted in Bahasa Indonesia with the help of an Indonesian research assistant who had extensive prior research experience and a very good knowledge of the English language.

Initial participants for household interviews in the village were chosen based on their relevance for the research topic, e.g. length of time lived in Bungku. Subsequent interview partners were chosen by the snowball sampling method (Schnell et al. 2013), aiming to represent the social structure of the village hamlets. Focus group discussions were conducted with groups of six independent oil palm farmers to gain insights into local attitudes and concerns regarding oil palm cultivation. All interview activities were audio-recorded and written down in form of detailed chronological protocols in English language. Data processing and analysis followed the principles of a qualitative analysis of content (after Mayring 2002). Additional personal profiles of the interview partners allowed for an empirical typification (Kluge 2000) of the participants.

METHODOLOGY OF CLIMATE CHANGE ANALYSIS

We used the Standardized Precipitation Evapotranspiration Index (SPEI), which takes into account precipitation and potential evapotranspiration, to determine drought conditions. Using the Global SPEI database (SPEIbase, Vicente-Serrano et al. 2010), which offers information about SPEI at the global scale with a 0.5 degrees resolution and monthly time resolution, we evaluated drought changes from 1900 until 2011 in Bungku area (E 103.25, S 1.25). The SPEIbase is based on monthly precipitation and potential evapotranspiration from the Climatic Research Unit of the University of East Anglia (CRUE TS 3.2 dataset).

Additionally, we analyzed air temperature and rainfall data from 1991 to 2011 from the meteorological station, property of the Indonesian meteorological service (BMKG), located at the Airport Sultan Thaha in Jambi. Rainfall was recorded daily, while temperature was manually recorded three times a day (7, 13 and 18 h). Daily average temperature was calculated by double counting the measurement at 7 am (to consider the lower temperatures during the night) and averaging it with the temperatures measured during the rest of the day. Daily minimum and maximum temperatures were also recorded. Data series were separated into its time components in order to detect possible changes in their trend over the period of study.

Appendix 1 Detailed Method Description

METHODOLOGY OF ENVIRONMENTAL MEASUREMENTS

Evapotranspiration

The eddy covariance technique (Baldocchi et al. 2003) was used to measure evapotranspiration (ET) in a 12-year old oil palm plantation in Indonesia. In the oil palm plantation (S1.693 E 103.391, at approximately 25 km from Bungku, Fig. 1), a 22 m high tower, equipped with a sonic anemometer (Metek uSonic-3 Scientific, Elmshorn, Germany) to measure the three components of the wind vector, and an open path carbon dioxide and water analyzer (Li-7500A, Licor_Inc, Lincoln, USA), was running from March 2014 until December 2014. Evapotranspiration fluxes were calculated using the software EddyPro, planar-fit coordinate rotated, corrected for air density fluctuation and quality controlled (Meijide et al., in preparation). For this analysis, ET was estimated using data from three sunny days during the period of July-August 2014, using daytime (6 am-7 pm) data, in order to avoid possible measurement errors as a consequence of low turbulent conditions during nighttime hours.

Transpiration

To derive transpiration rates, we used the thermal dissipation probe (TPD, Granier, 1985, 1996) method to measure sap flux density (*SFD*) in leaf petioles of oil palms and in the trunks of dicot trees. For oil palm, 16 TDP sensors (1.25 cm length) were installed on the underside of oil palm leaf petioles on four palms of varying height per plot (see Niu et al. 2015 for details). For forest and rubber plots, two sensors were installed at breast height in the North and South, respectively, of six (rubber) or eight (forest) tree trunks per plot (2.5 cm sensor length). In the forest, we chose dominant and co-dominant individuals only, as they are expected to account for the major part of stand water use; within the dominant and co-dominant sociological classes, we evenly selected individuals of relatively larger, medium and smaller diameters (min. diameter at breast height: 10 cm).

After sensor installation, insulative materials and aluminum foil were added to minimize temperature gradients and reflect radiation. Durable plastic foil was added for protection from rain. The sensors were connected to AM16/32 multiplexers connected to a CR1000 data logger (both Campbell Scientific Inc., Logan, USA). The signals from the sensors were recorded every 30 sec and averaged and stored every 10 min. In each plot, *SFD* was measured for a minimum period of three weeks. For oil palm, the mV-data from the logger were converted to *SFD* (g cm^{-2} h^{-1}) with the equation by Granier (1985), but with an adjusted set of equation parameters *a* and *b* that was specifically derived for TDP measurements on oil palm leaf petioles (Niu et al. 2015). As for oil palm by Niu et al. (2015), the TDP method was tested against gravimetric measurements in the laboratory for rubber and forest trees. The gravimetric readings and the estimates using the original Granier equation were within the 95 % confidence interval of a linear regression with a slope of 1. Thus, the original equation parameters (Granier 1985) were used for the analysis of rubber and forest trees.

Appendix 1 Detailed Method Description

To upscale from sap-flux point-measurements to water use rates per plant (kg day^{-1}) and ultimately to stand transpiration (mm day^{-1}), water conductive areas (cm^2) had to be established for each of the studied individuals and stands. For oil palm leaf petioles at the location of sensor installation, we used a linear regression between leaf baseline length and leaf conductive area, which was derived by Niu et al. (2015) for oil palms in the same study region based on laboratory staining experiments. To derive water conductive areas for dicot trees in forest and rubber plots, we measured the radial patterns of *SFD* with increasing depth (*d*, cm) into the xylem (0-8 cm, 1 cm resolution) with heat field deformation sensors (HFD, Nadezhdina, 2012, sensors from ICT International, Armidale, Australia) in 10 individuals per land use type. The measurements were conducted in parallel to TDP measurements (0-2.5 cm depth) on these individuals; HFD sensors were installed in between TDP sensors (North and South), i.e. in the West, at a similar height on the tree. The radial *SFD* patterns obtained by the HFD measurements were normalized to a depth of 1.25 cm (center of TDP sensors) to allow for an extrapolation of the single-point TDP measurements in the outer xylem (0-2.5 cm) to whole-tree water use rates (following Oishi et al. 2008). To subsequently upscale to stand-scale transpiration rates inventory data were used.

The sap flux measurements were conducted between March 2013 and April 2014. As most measurements could not be conducted in parallel for logistical reasons, we used the respective averages of the three most sunny and dry days within each measurement period (min. 3 weeks) for the analysis of the spatial variability in transpiration rates between plots, as to minimize day-to-day variability induced by weather.

Soil characteristics and erosion

Soil samples were collected per horizon in one soil pit on each plot. The subsoil under plantations was not affected by enhanced decomposition processes after forest conversion (Guillaume et al. 2015). Carbon content and C/N ratio below the Ah horizons were similar under forest and plantations. Therefore, we assessed erosion by assuming C isotopic composition ($\delta^{13}C$ values) in the plantation subsoil was similar to the values in the forest subsoil prior to conversion. Consequently, when an identical subsoil depth has a higher $\delta^{13}C$ in the plantation than the forest, we suggest that this layer experienced a vertical shift towards the soil surface after erosional loss of the upper layer.

A power function describing the increase of $\delta^{13}C$ with depth under forest was fitted in Statistica 10 using Equation A1.1.

$$\delta^{13}C_d = \delta^{13}C_{Ah} d^l \quad (A1.1)$$

where C(d), $\delta^{13}C(d)$, C(Ah) and $\delta^{13}C(Ah)$ are the C content and the $\delta^{13}C$ value estimated for the depth *d* and measured in the Ah horizon, respectively, *d* the depth in cm and l the fitted parameters of the function. Regressions were fitted using all samples below the Ah horizons in the four forest replicate plots.

Appendix 1 Detailed Method Description

Erosion was calculated using the power function describing the distribution of $\delta^{13}C$ with soil depth in the forest plots. Assuming that the shift in $\delta^{13}C$ in the plantation subsoil resulted from shift in the depth due to the erosion after conversion, we calculated the original depth before erosion for all samples under plantations by modifying Equation A1.2:

$$d_b = 10^{\frac{log_{10}(\delta 13C_d/\delta 13C_{Ah})}{-l}} \quad \text{(A1.2)}$$

where d_b is the estimated depth before the conversion to plantation, $\delta^{13}C_d$ is the $\delta^{13}C$ values of the samples under plantation at depth d, $\delta^{13}C_{Ah}$ is the mean $\delta^{13}C$ values of the Ah horizons under forest, and l is the parameters estimated for the soils under forest. The difference between the estimated depth before conversion (d_b) and depth at which the sample was collected (d) corresponds to erosion. The erosion for one plantation plot was calculated by averaging the erosion estimated for each sample collected in the plot. We excluded Ah horizons and samples deeper than 77 cm, which corresponds to the deepest sample under forest.

Microclimatic effects of land use change

A 2.5 m aluminum mast was placed in the center of the plots. A thermo-hygrometer (Galltec Mella, Bondorf, Germany) was installed at 2 m height in the mast and a soil temperature and moisture sensor (Trime-Pico 32, IMKO, Ettlingen, Germany) was placed 0.3 m under the soil surface. Both sensors were connected to a data logger (LogTrans16-GPRS, UIT, Dresden, Germany). Data were recorded every hour, for 16 months from June 2013 on.

Micro-catchment related measurements

General catchment characteristics

Within two small catchments partly encompassing the oil palm and rubber plantations (plots HO1-4, HR1-4, Fig. 1), we recorded streamflow and measured rainfall interception for four months. One catchment (extension of 14.2 ha) was dominated by 10-14 year-old oil palm plantations (90 % of the area). The other catchment (4.9 ha) consisted of different rubber stands: eight year-old (19 % of the area) and 30 year-old (56 % of the area) mono-culture rubber plantations and jungle rubber (25 % of the area), a mix of rubber trees and naturally established dicot tree species. We selected a two week period (7 to 20 Nov 2013) of the recorded hydrographs encompassing both dry and rainy conditions. Rainfall interception of the oil palm and rubber monocultures in the respective catchments was assessed by measuring throughfall and stemflow, and subtracting them from incident rainfall.

Precipitation

We measured incident rainfall with three ombrometers (154 cm^2 collection area each) in open areas no more than 100 m from the respective catchments. Data were recorded manually at 6 am every day. We observed 30 rainfall events during our measurement period from November 2012 to February 2013, ranging from light to heavy rain (see Fig. A1.1).

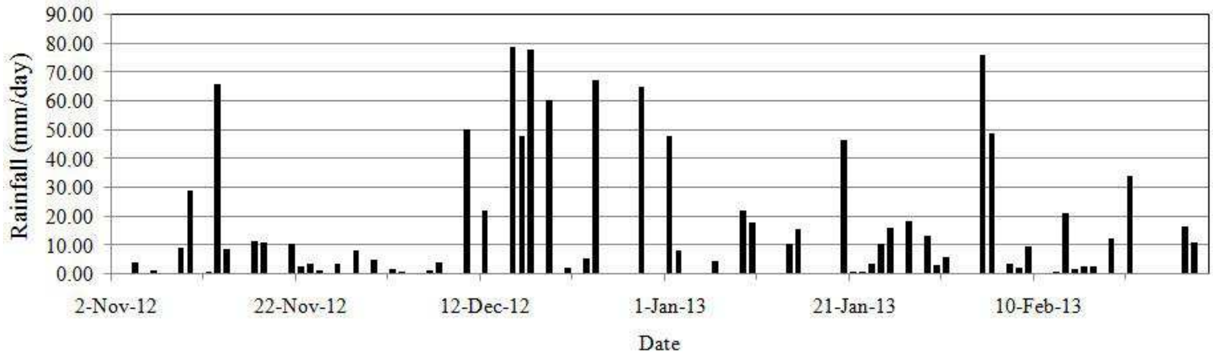

Fig. A1.1. Quantities of daily rainfall in the study area from November 2012 to February 2013.

Streamflow

The two catchments were instrumented with a rectangular weir. The water levels in the weirs were continuously recorded using a HOBO Water Level Data Logger (Type U20-001-01, Onset, Bourne, MA, USA). Recorded water levels were converted to discharge units using Equation A1.3.

$$Q_r = 0.57\ H^{1.44} \quad \text{(A1.3)}$$

Where Q_r is rectangular weir discharge (l s^{-1}) and H is the water level in the weir (cm).

Throughfall

Throughfall samplers were made of 10-liter-canisters with funnels attached to the top for water collection. In oil palm plantations, the samplers were installed in diagonal patterns between adjacent palms. In total, the measurements were carried out in eight diagonal lines, where four lines represent 2 m and 4 m distance from respective trunks and the remaining four lines represent 1 m and 3 m distance from the trunk. Combined, the throughfall data thus had a resolution of 1 m. In rubber plantations, throughfall samplers were placed between adjacent rubber trees at distances of 1 m and 2 m from the trunk. Recordings were taken daily between November 2012 and February 2013.

Stemflow

Stemflow was measured by circling and sticking semicircle-shaped metal sheets from the top to the bottom of the trunk. The circling ended 50 cm above ground to allow for the placement of water collectors beneath it. Stemflow collectors were installed on four oil palm and six rubber trunks, respectively. The measurements were conducted between November 2012 and February 2013.

Interception

Interception was calculated by subtracting stemflow and throughfall from incident rainfall at the plot scale. Given that interception is based on the area of palm or tree canopy cover, stemflow data were normalized with canopy area before subtraction. Throughfall values on the canopy level were obtained by averaging measurements at various distances from the trunks of several individuals.

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