1   **Hydrologically transported dissolved organic carbon influences soil respiration in a tropical**

2   **rainforest**

3   **Running title: DOC influences soil respiration**

4   Author: W.-J. Zhou [1,2,3], H.-Z. Lu [1,2,3], Y.-P. Zhang [1,2*], L.-Q. Sha [1,2*], D. Schaefer [1,2], Q.-H. Song [1,2,3],

5   Y. Deng [1,2], X.-B. Deng[1,2]

6   Affiliation:

7   [1.]   Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden,

8   Chinese Academy of Sciences, Mengla, Yunnan 666303, China

9   [2.]   Xishuangbanna Station for Tropical Rain Forest Ecosystem Studies, Chinese Ecosystem

10   Research Net, Mengla, Yunnan 666303, China

11   [3.]   Graduate University of the Chinese Academy of Sciences, Beijing 100039, China

12   **Corresponding author:**

13   Y.-P. Zhang, Tel: +86-871-65160904, Fax: +86-871-65160916, E-mail: yipingzh@xtbg.ac.cn

14   L.-Q.Sha, Tel: +86-871-65160904, Fax: +86-871-65160916, E-mail: shalq@xtbg.ac.cn

15   **Keywords:**

16   Dissolved organic carbon (DOC), Soil temperature, Soil water content, Soil respiration, Tropical

17   rainforest

18   **Paper type:**

19   Primary research articles

20   **Abstract**

21   To better understand the effect of the dissolved organic carbon (DOC) transported by hydrological

22   processes (rainfall, throughfall, litter leachate, and surface soil water (0–20 cm)) on soil respiration in

23   tropical rainforests, we detected the DOC flux in rainfall, throughfall, litter leachate, and surface soil

24   water (0–20 cm), compared the seasonality of $\delta^{13}C_{DOC}$ in each hydrological process, and $\delta^{13}C$ in leaves,

25   litter, and surface soil, and analyzed throughfall, litter leachate, and surface soil water (0–20 cm) effect

26   on soil respiration in a tropical rainforest in Xishuangbanna, southwest China. Results showed: The

27   surface soil intercepted 94.4 ± 1.2% of the annual litter leachate DOC flux and is a sink for DOC. The

28   throughfall and litter leachate DOC fluxes amounted to 6.81% and 7.23% of the net ecosystem

29   exchange, respectively, indicating that the DOC flux through hydrological processes is an important

30   component of the carbon budget, and may be an important link between hydrological processes and

31   soil respiration in a tropical rainforest. Even the variability in soil respiration is more dependent on the

32   hydrologically transported water than DOC flux insignificantly, soil temperature and soil water content

33   (at 0–20 cm). The difference in $\delta^{13}C$ between the soil, soil water (at 0–20 cm), throughfall, and litter

34   leachate indicated that DOC is transformed in the surface soil and decreased the sensitivity indices of

35   soil respiration of DOC flux to water flux, which suggests that soil respiration is more sensitive to the

36   DOC flux in hydrological processes, especially the soil water DOC flux, than to soil temperature or soil

37   moisture.

1. Introduction

Dissolved organic carbon (DOC), the most active form of fresh carbon, stimulates microbial activity

and affects CO_2 emissions from the surface soil (Bianchi, 2011, Chantigny, 2003, Cleveland et al.,

2006). This indicates that the proportion of DOC that leaches from the soil is a crucial component of

the carbon balance (Kindler et al., 2011, Stephan et al., 2001), which is also estimated as the high ratio

of DOC flux to net ecosystem exchange (NEE) in forests, grasslands, and croplands (Sowerby et al.,

2010). The DOC from water-extractable soil carbon is regenerated quickly and functions as an

important source of substrate for soil respiration (SR), especially microbial heterotrophic respiration

(HR) (Cleveland et al., 2004, Jandl and Sollins, 1997, Schwendenmann and Veldkamp, 2005), which

contributes more to SR than does autotrophic respiration. Laboratory studies have shown that DOC

also plays an important role in SR in the surface soil (De Troyer et al., 2011, Fröberg et al., 2005, Qiao

et al., 2013). However the mechanisms underlying the effects of DOC on the carbon budget and SR in

the field remain unclear.

Hydrological processes that transport DOC, such as throughfall and litter leachate, are important

sources of DOC in surface soil water (De Troyer et al., 2011, Kalbitz et al., 2000, Kalbitz et al., 2007,

Kindler et al., 2011). The soil retains most of the DOC that reaches the soil surface from the throughfall

and litter leachate (Chuyong et al., 2004, Dezzeo and Chacón, 2006, Liu and Sheu, 2003, Liu et al.,

2008, McJannet et al., 2007, Schrumpf et al., 2006, Zimmermann et al., 2007). Qiao et al. (2013)

suggested that the addition of labile organic carbon increases the decomposition of the native soil

organic carbon (SOC) by exerting a priming effect, and augments the CO_2 emissions in subtropical

59   forests. Because of the massive rainfall in tropical rainforests, more DOC flux is transported to the soil

60   by throughfall and litter leachate than in other forests. The high temperature and leaching in tropical

61   forests may mean that the fresh DOC from hydrological processes affects SR differently in tropical

62   rainforests than in boreal and temperate forests (De Troyer et $al.$, 2011, Fröberg et $al.$, 2005, Qiao et $al.$,

63   2013). For this reason, research into the role of hydrologically transported DOC in the SR in tropical

64   rainforest is essential.

65   The fate of DOC intercepted by the surface soil can be determined from variations in the DOC flux and

66    $\delta^{13}C_{DOC}$ among soil water, soil, litter leachate, and throughfall. Based on the seasonal and source

67   (canopy leaf, litter, or soil) differences in $\delta^{13}C$ (De Troyer et $al.$, 2011), $\delta^{13}C_{DOC}$ studies have shown

68   that DOC transported from aboveground water and from the desorption of soil aggregates is retained in

69   the surface soil by soil absorption or is involved in surface carbon biochemical dynamics through soil

70   water leaching and microbiological activity (Comstedt et $al.$, 2007, De Troyer et $al.$, 2011, Fang et $al.$,

71   2009, Kindler et $al.$, 2011). This proposal has been confirmed in a laboratory leaching experiment

72   simulating a temperate forest, as performed by Park et $al.$ (2002), who reported that the cumulative

73   amount of CO_2 evolved is positively related to the availability of carbon (Park et $al.$, 2002).

74   Furthermore, fresh DOC fed to the surface soil influences soil CO_2 emissions in both the short term

75   (3–14 days) and long term (month to years) (Davidson et $al.$, 2012). Therefore, several models of the

76   surface soil carbon efflux indicate that DOC is a factor that influences CO_2 emissions (Blagodatskaya

77   et $al.,$ 2011, Guenet et $al.$, 2010, Yakov, 2010) based on recent research with controlled experiments.

78   However, the natural mechanism underlying the effects of the hydrologically transported DOC flux on

79   CO_2 emissions remains unclear. The precipitation rate, NEE, and litterfall are all high in tropical forests

80   (Tan et $al.$, 2010, Zhang et $al.$, 2010), and several studies have shown that DOC plays an important role

4

81   in the carbon balance in these settings (Fontaine *et al.*, 2007, McClain *et al.*, 1997, Monteith *et al.*,

82   2007). Here, we investigate the relative contribution of hydrologically transported DOC to SR in a

83   rainforest compared with the contributions of soil temperature and moisture, which has not been

84   extensively studied until now.

85   Our study was performed in a tropical rainforest at Xishuangbanna in southwest China, on the northern

86   edge of a tropical region. This forest has less annual rainfall (1557 mm), a smaller carbon sink (1667 kg

87   C ha^{-1}) (Tan *et al.*, 2010, Zhang *et al.*, 2010), lower SR (5.34 kg CO_2 m^{-2} yr^{-1}) (Sha et al., 2005), and

88   less litterfall (9.47 $\pm$ 1.65 Mg C ha^{-1} yr^{-1}) (Tang *et al.*, 2010) than typical rainforests of the Amazon and

89   around the equator. We hypothesized that throughfall and litter leachate DOC flux are important in

90   carbon budget, and that hydrologically transported DOC significantly affects SR in the tropical

91   rainforest at Xishuangbanna. To test these hypotheses, we determined the SR, HR, and DOC fluxes in

92   the rainfall, throughfall, litter leachate, and surface soil water (0–20 cm depth), the seasonal variability

93   in δ^{13}C (isotopic abundance ratio of ^{13}C) in DOC ($\delta^{13}C_{DOC}$) and in the carbon pools in the soil, litter,

94   and canopy leaves in this tropical forest.

95   **2 Materials and methods**

96   2.1 Study site

97   The study site is located at the center of the National Forest Reserve in Menglun, Mengla County,

98   Yunnan Province, China (21°56′N, 101°15′E), and has suffered relatively little human disturbance. The

99   weather in the study area is dominated by the north tropical monsoon and is influenced by the

100   southwest monsoon, with an annual average temperature of 21.5 ℃, annual average rainfall of 1557

101   mm, and average relative humidity of 86%. Based on the precipitation dynamics, the rainy season

102   occurs between May and October (with 84.1% of the total annual precipitation) and the dry season

103   between November and April.

104   The dominant trees are *Terminalia myriocarpa* and *Pometia tomentosa*, which are typical tropical

105   forest trees. Canopy height is about 45m, the land cover ratio is 100%, there are 311 species that

106   diamater at breast height (DBH) is larger than 2cm (Cao *et al*., 1996). The topographic slope is

107   12 °–18 °, and the soil type is oxisol, formed from Cretaceous yellow sandstone, with a pH of 4.5–5.5

108   and a clay content (d < 0.002 mm) of 29.5% in the surface soil (0–20 cm) (Tang *et al*., 2007).

109   2.2 Experimental set-up

110   At the study plot (a 23.4 ha catchment), three rainfall collectors were set above the canopy on a 70 m

111   eddy flux tower to collect rain samples. Each collector had a polytetrafluoroethylene (PTFE) funnel

112   (2.5 cm diameter) connected to a brown glass bottle, which was rinsed with distilled water before each

113   collection. There were four replicates of throughfall, litter leachate, and soil water (20 cm depth)

114   respectively. All the collectors were set around the eddy flux tower randomly. All the collectors were

115   distributed randomly around the eddy flux tower. The throughfall collectors were $200 \times 40 \ cm^2$

116   V-shaped tanks made of stainless steel. A PTFE tube connected the collector to a polyethylene

117   sampling barrel. The litter leachate was collected in 40 cm $\times$ 30 cm $\times$ 2 cm PTFE plates. In the plate,

118   we layered 100-, 20-, and 1-mesh silica sand from the bottom to the upper edge, to a depth of 2 cm, to

119   ensure that the litterfall fragments did not reach the bottom of the plate and to filter the leachate. The

120   bottom of the plate was curved into an arc shape, causing the leachate to flow together at the bottom

121   funnel. The funnel was connected by a PTFE tube to a 10 L bottle further down the slope. The soil

122   water collector was designed like the litter leachate collector. The collection system was buried in soil

123   at a depth of 20 cm along the surface slope. To reduce the disturbance from digging as much as

124   possible, all the soil collectors were placed in holes that were approximately the size of the PTFE

125   collector, and all soil was added from the bottom to the surface, layer by layer. All the soil water and

126   litter leachate collectors were set in place 3 months before the samples were collected, to minimize the

127   influence of their installation.

128   The water fluxes from rainfall and throughfall were estimated with an installed water-level recorder.

129   The recorder was set to measure the average discharge at 30 min intervals. The daily and weekly water

130   fluxes from rainfall and throughfall were calculated from the data recorded automatically between

131   08:00 and 08:00 on the following day (local time). The water fluxes from the litter leachate and soil

132   water were determined daily by manual observation.

133   We set four 5 m × 5 m plots around the eddy flux tower to measure SR and HR using the trenching

134   method. In each plot, three paired trenches and control treatments were used to detect both HR and SR.

135   Each treatment covered an area of 50×50 cm^2. Most fine roots occur in the first 0–20 cm of soil and

136   few occur below a depth of 50 cm in the soil of tropical rainforests. In each trenched treatment, a

137   polyvinyl chloride panel was installed, and a 50-cm-deep trench was filled with *in situ* soil to protect

138   root respiration during the trenching treatment.

139   The soil respiration was measured using a Li-820 system (Li-Cor Inc., Lincoln, NE,

140   USA), which consisted of an infrared gas analyzer with a polyvinyl chloride chamber(diameter of

141   15cm and height of 15.0 cm). A polyvinyl chloride collar (diameter of 15cm an height of 5cm) was

142   installed in the forest floor to a depth of ~3 cm. All the leaf litter and small branches were left in the

143   collar. Soil respirations were detected from 09:00 to 14:00 local time when was taken to represent

144   respiration in that day (Sha et al. 2005, Yao et al. 2011) biweekly from February 2008 to February

145   2009.

Soil temperature and moisture

147   From 2008 to 2011, soil temperature and moisture at a depth of 5 cm were measured every 15 min with

148   a Campbell Scientific data logger (Campbell Scientific, North Longan, Utah, USA) which was fixed to

149   the eddy flux tower. The daily average soil temperature and moisture were calculated as the daily

150   means of the data collected every 15 min.

151   During soil respiration observation period between February 2008 and January 2009, soil water content

152   (0–12 cm) was detected by time-domain reflectometry (TDR100, Campbell Scientific, USA) in the soil

153   close to every chamber. At the same time, the soil temperature (0–10 cm) and the air temperature were

154   recorded with a needle thermometer.

Soil, leaf, and litter sampling

156   Soil (0–20 cm depth) near the soil water collectors, and leaf samples and litter samples from around the

157   water collector were collected in August and October, 2010, and in January, March, and May, 2011.

158   The leaves of the dominant species were randomly picked from the canopy around the plots, and litter

159   samples were collected from around the plots. Soil samples were collected with a steel soil sampler

160   (diameter = 5 cm, height = 20 cm). All the leaf and litter samples were oven-dried to constant weight at

161   60 ℃. After drying, the leaf and litter were ground and passed through a 1 mm screen. Wind-dried soil

162   was manually broken by hand and sieved (100 mesh) to remove larger particles, roots, and visible soil

163   fauna. Plant and soil samples were analyzed for total C and $\delta^{13}C$ values with an elemental analyzer

164   (Elementar vario PYRO cube, Germany) coupled to an continuous flow system isotope ratio mass

165   spectrometer (IsoPrime 100 Isotope Ratio Mass Spectrometer, Germany, EA-MS). Samples (1.00-3.00

166   mg plant samples and 10-40 mg soil sample dried and sieved through 100 mesh size) were wrapped in

167   a tin boat and loaded into the auto-sampler (EA3000, Eurovector, Milan, Italy) coupled to the

168   EA-IRMS. The sample was flash combusted in a combustion reactor held at 1120℃. The produced

169   CO_2 was separated by the CO_2 absorption column, and carried by helium to ion source for

170   measurements. The reference CO_2 (>99.999%) flowed in at 420 seconds and lasted for 30 seconds. The

171   isotopic results are expressed in standard notation ($\delta^{13}C$) in parts per thousand (‰) relative to the

172   standard Pee Dee Belemnite:

173    $\delta^{13}C = [^{13}R_{sample}/^{13}R_{standard} - 1] \times 1000$ (1)

174   where R is the molar ratio $^{13}C/^{12}C$.

175

176   **2.3 Water sampling and analysis**

177   All the 24 h cumulative water samples were collected at the sampling sites between 08:00 and 10:00

178   (local time), following the procedure outlined by Zhou et al. (2013), using high-density polyethylene

179   bottles. The sampling bottles were completely filled, allowing no headspace. After the bottles were

180   washed with 3% HCl solution, they were rinsed with distilled water. Before sample collection, the

181   bottles were pre-rinsed three times with the sample water. The study was performed over three full

182   calendar years, from January 1, 2009, to December 31, 2011. The water samples were collected on the

183   day following a rain event during the dry season and once a week during the rainy season in 2009, and

184   once a week in 2010 and 2011. All the water samples were immediately transported to the laboratory in

185   insulated bags to prevent DOC decomposition.

186   Based on the analytical method of Zhou *et al*. (2013), all the samples were vacuum-filtered through a

187   0.45 μm glass fiber filter (Tianjinshi Dongfang Changtai Environmental Protection Technology,

188   Tianjin, China) and were pre-rinsed with deionized water and the sample water under vacuum. The

189 filtered samples were analyzed for DOC within 24 h of collection using a total organic carbon/total

190 nitrogen (TOC/TN) analyzer (LiquiTOC II, Elemental Analyses System GmbH, Germany).

191 To analyze the water DOC isotopic δ^{13}C-DOC ($\delta^{13}C_{DOC}$), the samples were collected on the same day

192 as the leaves, litter, and 0–20 cm soil samples were collected. Subsamples (500 mL) of the rain,

193 throughfall, litter leachate, and soil water samples were passed through a 0.45 μm glass fiber filter and

194 transferred to another 500 mL polyethylene terephthalate bottle. All the filtered water was frozen and

195 placed in a freeze dryer until it was reduced to a fine powder. The δ^{13}C of the freeze-dried DOC was

196 analyzed with a method similar to that for the plant and soil samples. Considering the lower C content,

197 more sample amount (20-60mg) were weighted, the combustion temperature was set at 920℃, and the

198 reference CO_2 flowed in at 475 seconds, later than for the soil and plant samples. The sample δ^{13}C

199 abundance were calculated according to Eq (1).

200 2.4 Calculations and statistics

201 The correlations among the daily water flux and DOC concentration, SR, HR, soil moisture, and soil

202 temperature from February 2008 to January 2009, and the weekly SR and HR rates and the amounts of

203 DOC and water in 2009–2011 were tested with Pearson's correlation (two-tailed) and nonlinear

204 regression tests. One-way analysis of variance (ANOVA) was used to compare the hydrological DOC

205 fluxes among different hydrological processes. The seasonal difference of hydrological DOC fluxes,

206 $\delta^{13}C_{DOC}$ was tested by independent sample t test. The SPSS 15.0 software was used for all calculations.

207 Because the individual correlations between the water flux and the DOC concentration in the

208 throughfall, litter leachate, and soil water were significant (Fig. S1), the regression equations used for

209 the water flux and DOC concentration ($Y = ae^{bx}$) were as follows:

210 $C_{TF} = 48.69e^{-0.097x}$ adjusted $r^2 = 0.3883$, $p = 0.002$ (2)

211 $C_{LL} = 60.93e^{-0.048x}$ adjusted $r^2 = 0.4131$, $p < 0.001$ (3)

212 $C_{sw20} = 6.78e^{-0.02048x}$ adjusted $r^2 = 0.5840$, $p < 0.001$ (4)

213 where C_{TF}, C_{LL}, and C_{sw20} are the DOC concentrations (mg L^{-1}) in the throughfall, litter leachate, and

214 soil water (0–20 cm), respectively, and x is the water flux per day (mm d^{-1}).

215 We did not collect all the individual rainfall events, throughfall, litter leachate, and soil water samples

216 to analyze the DOC concentrations, but interpolated all the DOC concentrations and water fluxes

217 according to eq(2)–(4).

218   The daily DOC flux was calculated as

219 $F = CV/100$ (5)

220 where F is the daily DOC flux (kg C ha^{-1} d^{-1}), C is the DOC concentration (mg L^{-1}), and V is the water

221 flux (mm d^{-1}) per day.

222 The weekly carbon flux (kg C ha^{-1} $week^{-1}$) was calculated as the sum of the daily DOC fluxes.

223 Soil temperature and soil water content of eddy flux tower explained 89.96% and 80.57% dynamic of

224 that of soil respiration observation plot from Feb. 2008 to Jan. 2009 respectively, and the correlations

225 between soil temperature at a depth of 5 cm and both SR and HR were strong (Fig. S2) between

226 February 2008 and January 2009. SR and HR during the period from January 1, 2009 to December 31,

227 2011 were calculated based on the equation $Y = ae^{bx}$ from the data collected between February 2008

228 and January 2009, as follows:

229 $SR = 46.37e^{(0.11T5)}$ $r^2 = 0.8966$, $p < 0.0001$ (6)

230 $HR = 18.90e^{(0.14T5)}$ $r^2 = 0.8372$, $p < 0.0001$ (7)

231 where SR is total soil respiration (mg CO_2 m^{-2} h^{-1}), HR is heterotrophic respiration (mg CO_2 m^{-2} h^{-1}),

232   and T5 is soil temperature at 5 cm depth.

233   Sensitivity indices calculations

234   Firstly, weekly soil respirations fluxes, weekly average of soil temperature and soil water content,

235   weekly water and DOC fluxes were standardized by the ratio of measured value to the mean value

236   during the observation period. Secondly, linear regression equitation was used between the

237   standardized soil respirations values and T, SWC, water and DOC fluxes respectively. Thirdly, we

238   considered the slope of the linear regression as the sensitivity indices which showed the soil

239   respirations variation rate with soil temperature, soil water content, water and DOC fluxes changing.

240   **3 Results**

241   3.1 Water and DOC fluxes in a tropical rainforest

242   The seasonal and annual water fluxes decreased from the rainfall to the surface soil (Fig. 1a). The

243   interception rate of the water between hydrological processes was higher in the dry season than in the

244   rainy season (Fig. 1a, Table 1). The highest annual interception rate was between the litter leachate and

245   the surface soil (63.85 $\pm$ 7.98%), which was 62.19 $\pm$ 15.07% in the rainy season and 81.64 $\pm$ 23.38% in

246   the dry season.

247   The seasonal dynamics of the DOC flux were similar to those of the water flux (Fig. 1, Table 1). The

248   annual DOC flux increased from rainfall (41.9 $\pm$ 3.8kg C ha^{-1} yr^{-1}) to throughfall (113.5 $\pm$ 8.5 kg C ha^{-1}

249   yr^{-1}) and to litter leachate (127.7 $\pm$ 8.5 kg C ha^{-1} yr^{-1}), and then decreased sharply to the surface soil at

250   0–20 cm (7.07 $\pm$ 1.4 kg C ha^{-1} yr^{-1}) (Fig. 1b). The surface soil intercepted most of the DOC coming

251   from the previous layer (annual: 94.4 $\pm$ 1.2%, dry season: 96.7 $\pm$ 4.4%, rainy season: 93.9 $\pm$ 2.6%).

252   That the interception rates for water and DOC were greatest in the surface soil indicates the surface soil

253   is the most important water and DOC sink in this tropical rainforest (Table 1).

254   3.2 Isotopic characteristics of DOC in the hydrological processes of a tropical rainforest

255   During the transfer of rainfall to soil water (0–20 cm), $\delta^{13}C_{DOC}$ was highest in the rainfall DOC and

256   lowest in the throughfall DOC in both the rainy and dry seasons (Table 2). The seasonal difference in

257    $\delta^{13}C_{DOC}$ was highest in the surface soil water (3.25‰) and lowest in the litter leachate (0.11‰). From

258   the litter leachate to the surface soil water, $\delta^{13}C_{DOC}$ increased significantly by 4.26‰ ($p = 0.05$) in the

259   rainy season, but increased by only 1.12‰ (not significant, $p = 0.39$) in the dry season. $\delta^{13}C$ increased

260   from the canopy leaves to the soil and did not differ significantly between seasons (Table 2).

261   In both the dry and rainy seasons, $\delta^{13}C_{DOC}$ in water was higher than $\delta^{13}C$ in the corresponding element

262   (comparing throughfall with leaves, litter leachate with litter, and soil water with soil at 20 cm depth)

263   (Table 2). The smallest difference between $\delta^{13}C_{DOC}$ and $\delta^{13}C$ in each compartment occurred between

264   soil water DOC and soil carbon in the dry season, which was only 0.23‰. The greater difference

265   between $\delta^{13}C_{DOC}$ and $\delta^{13}C$ in the rainy season than in the dry season for soil water and soil (Table 2)

266   indicates that the biogeochemical dynamics of DOC are more active in the rainy season than in the dry

267   season in soil.

268   3.3 Surface soil CO_2 flux dynamics in a tropical rainforest

269   In the tropical rainforest at Xishuangbanna, SR was dominated by HR (Fig. 2). HR contributed more to

270   SR during the rainy season (76.8 ± 0.8%) than during the dry season (66.5 ± 0.5%), and the annual

271   contribution of HR to SR was 71.7 ± 0.7%. SR and HR were higher in the rainy season than in the dry

272   season, similar to the dynamics of the hydrological and DOC fluxes (Fig. 1).

273   Standardized soil temperature explained 98.7% and 98.2% of the variation in standardized SR and HR,

274 respectively, and standardized soil moisture explained 55.8% and 56.8% of the variation in

275 standardized SR and HR, respectively (Table 3). The sensitivity indices of SR and HR for soil

276 temperature at a depth of 10 cm were 0.56 and 0.46, respectively, whereas their sensitivity indices for

277 soil moisture were 0.65 and 0.53, respectively, based on observational data (Table 3, Fig. S2).

278 3.4 Influence of DOC flux on soil CO_2 flux in a tropical rainforest

279 There were significant correlations between the standardized weekly SR and HR and the standardized

280 weekly water fluxes and DOC fluxes through the hydrological processes (Table 3). Based on the

281 definition of the temperature-dependent sensitivity index for soil respirations, which is the slope of

282 standardized soil respirations caused by increase in standardized temperature, we also defined a

283 soil-water-content-dependent sensitivity index, a DOC-flux-dependent sensitivity index, and a

284 water-flux-dependent sensitivity index in this study, analogous to the temperature-dependent sensitivity

285 index for SR (Table 3). An independent t test showed that the DOC-flux-dependent sensitivity indices

286 for SR (2.72 $\pm$ 0.51) and HR (2.21 $\pm$ 0.42) were significantly lower than the water-flux-dependent

287 sensitivity indices for SR (2.87 $\pm$ 0.52, t = -2.68, p = 0.06) and HR (2.33 $\pm$ 0.43, t = -2.57, p = 0.06),

288 respectively, which indicates that SR and HR were more sensitive to the water flux than to the DOC

289 flux through the hydrological processes. The significant difference was observed between the

290 water-flux-dependent indices (t = 13.78, p<0.001) for SR (2.87 $\pm$ 0.52) and HR (2.33 $\pm$ 0.43), or

291 between the DOC-flux-dependent indices (t = 13.12, p<0.001) for SR (2.72 $\pm$ 0.51) and HR (2.21 $\pm$

292 0.42).

293 The soil-water-content-dependent sensitivity indices for HR (0.53) and SR (0.65) were than the

294 soil-temperature-dependent sensitivity indices (HR, 0.46; SR, 0.56),but less than all the

14

295   water-flux-dependent and DOC-flux-dependent sensitivity indices for SR and HR (Table 3). This

296   indicates that SR and HR are more sensitive to the hydrological water flux and DOC flux than to the

297   soil water content and soil temperature. A comparison of the sensitivity indices for water flux, DOC

298   flux, soil temperature, and soil moisture in all the hydrological processes reveals that SR and HR were

299   most sensitive to the water flux (3.70) dynamics which is a little higher than DOC flux (3.57) in the soil

300   water (0–20 cm depth) when weekly variations in the Xishuangbanna tropical rainforest were

301   considered.

302   **4 Discussion**

303   Our results showed that the throughfall carried most of the DOC (113.5 $\pm$ 8.5 kg C ha^{-1} yr^{-1}) through

304   the hydrological processes in the Xishuangbanna tropical rainforest, which amounted to 6.81% of the

305   NEE (1.67×10^3 kg C ha^{-1} yr^{-1}) (Tan et al., 2010) in this tropical rainforest in southwest China. The

306   litter leachate DOC (127.7 $\pm$ 8.5 kg) accounted for 7.23% of the NEE in this forest. This result

307   indicates that the throughfall DOC is an important component of the tropical rainforest carbon budget.

308   The litter leachate fed a great deal of DOC to the soil, but the surface soil intercepted 94.4 $\pm$ 1.2%

309   (127.7 $\pm$ 8.0 kg) of the DOC, and the surface soil water DOC flux was only 7.1$\pm$1.4 kg C ha^{-1} yr^{-1},

310   which was slightly less than that at the headwater stream outlet (10.31 kg C ha^{-1} yr^{-1}) (Zhou et al.,

311   2013). The surface soil intercepted the bulk of the litter leachate DOC and transported little DOC to the

312   deep layer, indicating that the surface soil is the DOC sink in the tropical rainforest in Xishuangbanna.

313   The small seasonal differences in $\delta^{13}C_{DOC}$ in the rainfall, throughfall, and litter leachate indicate that

314   the DOC in the aboveground water is seasonally stable (Table 2). However, $\delta^{13}C_{DOC}$ in the soil water (at

315   0–20 cm) was higher in the rainy season (3.25‰) than in the dry season, indicating that the DOC

316 reaction in the surface soil is seasonal. In the dry season, $\delta^{13}C_{DOC}$ in the surface soil water (–27.1 ±

317 2.2‰) was similar to $\delta^{13}C_{DOC}$ in the soil (–27.3 ± 0.1‰), indicating that the soil is the major source of

318 soil water DOC. This is attributable to the combined absorption effects of the high clay content

319 (Fröberg, 2004, Lemma *et al*., 2007, Sanderman and Amundson, 2008, Tang *et al*., 2007) and the lack

320 of water carrying DOC through the different compartments in the dry season. Therefore, most DOC is

321 locally produced rather than transported. Less water and the lower DOC input from litter leachate and

322 throughfall to the surface soil (Fig. 1) also contribute to a reduction in microbial activity, which

323 contributes negligibly to the soil DOC when the soil moisture and soil temperature are low in the dry

324 season (Wu *et al.*, 2009). In the rainy season, the soil water content and soil temperature are higher, so

325 there is more vigorous biogeochemical activity in the surface soil (Bengtson and Bengtsson, 2007).

326 Therefore, more DOC is released from the soil to be mineralized by microorganisms, and there is more

327 ^{13}C in the soil water DOC ($\delta^{13}C$ = –23.9 ± 2.2‰) than in the soil ($\delta^{13}C$, –27.3 ± 0.1‰). The relatively

328 low $\delta^{13}C_{DOC}$ in the litter leachate ($\delta^{13}C_{DOC}$ = –28.1 ± 2.7‰) compared with the soil water indicates that

329 the DOC from the litter leachate has attended in the carbon cycle in the surface soil (Cleveland *et al.*,

330 2006, De Troyer *et al*., 2011). Furthermore, most of the DOC from the throughfall, litter leachate, and

331 litter was fed to the surface soil, and the soil water $\delta^{13}C_{DOC}$ value was higher than that of the

332 throughfall, litter leachate DOC, and $\delta^{13}C$ soil (0–20 cm) values (Table 2). These data indicate that all

333 the DOC transported by the throughfall and litter leachate was ultimately involved in the surface soil

334 carbon cycle (Fröberg *et al*., 2003, 2005, Kammer *et al*., 2012), and has also contributed to the SR

335 because it is an important part of the surface soil carbon cycle in the tropical rainforest at

336 Xishuangbanna.

337 Laboratory-based studies of tropical forests have shown that DOC primes the soil CO_2 flux (Qiao *et al.*,

338 2013). A study of a temperate forest showed that the rate of DOC production is one of the rate-limiting

339 steps for SR (Bengtson and Bengtsson, 2007). Comparative studies of ^{13}C and ^{14}C in DOC and SOC

340 have also shown that fresh organic carbon stimulates the activity of old carbon, and increases the

341 emission of CO_2 because DOC is the substrate of microbial activity (Cleveland *et al.*,2004, 2006,

342 Hagedorn and Machwitz, 2007, Hagedorn *et al.*, 2004, Qiao *et al.*, 2013). Because the microbial

343 biomass and potential carbon mineralization rates are higher in soils with higher DOC contents than in

344 soils with lower DOC contents (Montaño *et al*., 2007), the DOC turnover rate (Bengtson and

345 Bengtsson, 2007) is rapid and the transformation period is short (3–14 days) (Cleveland *et al*., 2006,

346 De Troyer *et al*., 2011). This indicates that DOC is involved in the surface soil carbon cycle in the short

347 term by affecting SR (Cleveland *et al.*, 2004, 2006). Although we did not determine the period of the

348 DOC turnover cycle, the weekly DOC flux passing through the hydrological processes (throughfall,

349 litter leachate, soil water, and interception by the surface soil) significantly explained SR and HR, with

350 higher sensitively indices than the indices for the soil water content and soil temperature (Table 3),

351 predicting that DOC has a significant impact on soil CO_2 emissions in this tropical rainforest.

352 It is important to consider which part of the DOC flux in the hydrological processes of this tropical

353 rainforest most strongly influences SR. Previous studies have shown that of all the factors affecting SR,

354 it is most sensitive to soil temperature (Bekku *et al.*, 2003, Reichstein *et al*., 2003, Zheng *et al.*, 2009),

355 as in the tropical forest at Xishuangbanna (Sha *et al.*, 2005). Although soil temperature better explained

356 SR and HR than the DOC flux, the sensitivity indices for the soil water DOC fluxes were higher than

357 the sensitivity indices for soil temperature, although temperature explained the rate of SR better than

358 the DOC flux (Table 3). At this study site, HR, which depends predominantly on microbial activity and

359 substrates, contributed the major fraction of SR (Fig. S2), so not only HR, but also SR depends most

17

360   strongly on the microbial and respiratory substrates in this tropical rainforest. Therefore, the DOC

361   transported by the forest hydrological processes, from litter decomposition, root exudates, and the soil

362   itself, will contribute to SR (Table 2). The bioavailability of the DOC transported by hydrological

363   processes is greater than that of SOC (De Troyer *et al.*, 2011, Kindler *et al.*, 2011). The DOC from

364   throughfall and litter leachate is also an important contributor because $\delta^{13}C_{DOC}$ differs between the

365   surface soil water and the litter leachate and throughfall (Table 2). Although ectotrophic mycorrhizae

366   contribute significantly to SR in the rhizospheres of some temperate and boreal forests (Neumann *et al.*,

367   2014; Tomè *et al.*, 2016), in this tropical rainforest, EMF: *Paraglomus,* a kind of endomycorrhiza,

368   occupies more than 90% of the mycorrhizal community (Shi, 2014). Together with roots, and root

369   exudate, it contributes to the autotrophic SR, which is only 28.9% of the total SR, so the mycorrhiza is

370   not the dominant contributor to SR in this tropical rainforest. The other details of the biogeochemical

371   processes affecting DOC in the surface soil are not obvious in this study. However, according to both

372   laboratory and field studies, the DOC intercepted by the surface soil clearly affects HR (Table 3),

373   together with the DOC from litter decomposition and the soil itself (Cleveland *et al.*, 2004, 2006,

374   Hagedorn and Machwitz, 2007, Hagedorn *et al.*, 2004, Jandl and Sollins, 1997, Keiluweit *et al.*, 2015;

375   Montaño *et al.*, 2007, Qiao *et al.*, 2013, Schwendenmann and Veldkamp, 2005;). Considering the effect

376   of DOC on SR, the surface soil water DOC is the most sensitive index of HR and SR (Table 3).

377   The DOC-flux-dependent sensitivity indices for the different parts of the hydrological processes in this

378   tropical rainforest were a little less but insignificant than the amount-of-water-dependent sensitivity

379   indices, which shows that the DOC flux affects SR less than the amount of water passing through the

380   system, because of the combined effects of water and DOC on SR. According the DOC significant

381   contribution of soil respirations (Cleveland *et al.*, 2004, 2006, Hagedorn and Machwitz, 2007,

382   Hagedorn *et al.*, 2004, Qiao *et al.*, 2013), the little difference mechanisms between DOC and water flux

383   of tropical rainforest should be declared in the future study.

384   This study demonstrates that the surface soil is a sink for the DOC transported by hydrological

385   processes (Fig. 1), and that HR and SR are sensitive to the DOC flux through these processes. The most

386   sensitive indicator of SR is the soil water flux (at 0–20 cm) and followed by soil water DOC flux, both

387   exceeding the sensitivity of the soil temperature, soil water content, and other water flux, and DOC flux

388   along all the hydrological processes (Table 3). The variations in δ^{13}C in DOC, soil, and plants also

389   partly support the notion that the soil water DOC flux is the more sensitive index of SR in this tropical

390   rainforest. The results suggest that the DOC transported by hydrological processes plays the more

391   important role in the SR processes. In the context of global climate change, more attention must be paid

392   to the contribution of hydrologically transported DOC in future studies of the mechanisms of SR.

393   **Author contribution**

394   W.-J. Zhou and D. Schaefer, H.-Z. Lu, Sha L-Q, Y.-P Zhang designed the experiments and W.-J. Zhou,

395   H.-Z. Lu, Q.-H. Song, Y. Deng, X.-B. Deng carried them out. W-J Zhou prepared the manuscript with

396   contributions from all co-authors.

397

References

410 Bekku Y. S., Nakatsubo T., Kume, A., Adachi M., Koizumi, H.: Effect of warming on the temperature

411 dependence of soil, respiration rate in arctic, temperate and tropical soils, Appl. Soil. ecol., 22,

412 205–210, (2003)

413 Bengtson P., Bengtsson G. R.: Rapid turnover of DOC in temperate forests accounts for increased CO_2

414 production at elevated temperatures, Eco.Lett, 10, 783–790, 2007.

415 Bianchi T. S.: The role of terrestrially derived organic carbon in the coastal ocean: A changing

416 paradigm and the priming effect, P. Natl. Acad. Sci. USA., 108, 19473–19481, 2011.

417 Blagodatskaya E., Yuyukina T., Blagodatsky S., Kuzyakov Y.: Three-source-partitioning of microbial

418 biomass and of CO_2 efflux from soil to evaluate mechanisms of priming effects, Soil Biol.

419 Biochem., 43, 778–786, 2011.

420 Cao M., Zhang J., Feng Z., Deng J., Deng X.: Tree species composition of a seasonal rain forest in

421 Xishuangbanna, Southwest China, Trop. Ecol., **37**, 183–192, 1996.

422 Chantigny M.: Dissolved and water-extractable organic matter in soils: a review on the influence of

423 land use and management practices, Geoderma, 113, 357–380, 2003.

424   Chuyong G. B., Newbery D. M., Songwe N. C.: Rainfall input, throughfall and stemflow of nutrients in

425   a central African rain forest dominated by ectomycorrhizal trees, Biogeochemistry, **67**, 73–91,

426   2004.

427   Cleveland C. C., Neff J. C., Townsend A. R., Hood E.: Composition, dynamics, and fate of leached

428   dissolved organic matter in terrestrial ecosystems: results from a decomposition experiment,

429   Ecosystems, **7**: 175–285, 2004.

430   Cleveland C. C., Nemergut D. R., Schmidt S. K., Townsend A. R.: Increases in soil respiration

431   following labile carbon additions linked to rapid shifts in soil microbial community composition,

432   Biogeochemistry, **82**, 229–240, 2006.

433   Comstedt D., Boström B., Marshall J.D., Holm A., Slaney M., Linder S., Ekblad A.: Effects of elevated

434   atmospheric carbon dioxide and temperature on soil respiration in a boreal forest using $\delta^{13}C$ as a

435   labeling tool, Ecosystems, **9**, 1266–1277, 2007.

436   Davidson E.A., Samanta, S., Caramori, S.S., Savage, K.: The Dual Arrhenius and Michaelis-Menten

437   kinetics model for decomposition of soil organic matter at hourly to seasonal time scales, Global

438   Change Biol., 18, 371–384, 2012.

439   De Troyer, I., Amery F., Van Moorleghem C., Smolders E., Merckx R.: Tracing the source and fate of

440   dissolved organic matter in soil after incorporation of a ^{13}C labelled residue: A batch incubation

441   study, Soil Biol. Biochem, 43, 513–519, 2011.

442   Dezzeo N., Chacón N.: Nutrient fluxes in incident rainfall, throughfall, and stemflow in adjacent

443   primary and secondary forests of the Gran Sabana, southern Venezuela, Forest Eco. Manag., 234,

444   218–226, 2006.

445   Fang H.-J., Yu G.-R., Cheng S.-L., Mo J.-M., Yan J.-H., Li S.: ^{13}C abundance, water-soluble and

microbial biomass carbon as potential indicators of soil organic carbon dynamics in subtropical

forests at different successional stages and subject to different nitrogen loads, Plant Soil, 320,

243–254, 2009.

Fang Q.L., Sha L.: Fine roots turnover of tropical seasonal rain forest in Xishuangbanna, Yunnan, SW

China, Journal of Mountain Science, 23 (4):488-494, 2005.

Fontaine S., Barot S., Barré P., Bdioui N., Mary B., Rumpel C.: Stability of organic carbon in deep soil

layers controlled by fresh carbon supply, Nature, 450, 277–280, 2007.

Fröberg M.: Processes controlling production and transport of dissolved organic carbon in forest soils,

Doctoral thesis, 2004.

Fröberg, M., Berggren, D., Bergkvist, B., Bryant, C., Knicker, H.: Contributions of O_i, O_e and O_a

horizons to dissolved organic matter in forest floor leachates, Geoderma, 113, 311–322, 2003.

Fröberg, M., Kleja, D.B., Bergkvist, B., Tipping, E., Mulder, J.: Dissolved organic carbon leaching

from a coniferous forest floor – a field manipulation experiment, Biogeochemistry, 75, 271–287,

2005.

Guenet, B., Neill, C., Bardoux, G., Abbadie, L.: Is there a linear relationship between priming effect

intensity and the amount of organic matter input? Appl. Soil Ecol., 46, 436–442, 2010.

Hagedorn, F., Machwitz, M., 2007. Controls on dissolved organic matter leaching from forest litter

grown under elevated atmospheric CO_2, Soil Bio. Bioch., 39, 1759–1769, 2007.

Hagedorn, F., Saurer, M., Blaser, P.: A ^{13}C tracer study to identify the origin of dissolved organic

carbon in forested mineral soils, Eur. J. Soil Sci., 55, 91–100, 2004.

Jandl, R., Sollins, P.: Water extractable soil carbon in relation to the belowground carbon cycle, Bio.

Fer. Soils, 25, 196–201, 1997.

468   Kalbitz, K., Meyer, A., Yang, R., Gerstberger, P.: Response of dissolved organic matter in the forest

469   floor to long-term manipulation of litter and throughfall inputs, Biogeochemistry, 86, 301–318,

470   2007.

471   Kalbitz, K., Solinger, S., Park, J.-H., Michalzik, B., Matzner, E.: Controls on the dynamics of dissolved

472   organic matter in soils: a review, Soil Sci., 165, 277–304, 2000.

473   Kammer, A., Schmidt, M.W.I., Hagedorn, F.: Decomposition pathways of ^{13}C-depleted leaf litter in

474   forest soils of the Swiss Jura, Biogeochemistry, 108, 395–411, 2012.

475   Keiluweit, M., Bougoure, J. J., Nico, P. S., Pett-Ridge, J., Weber, P. K., Kleber, M.: Mineral protection

476   of soil carbon counteracted by root exudates, Nature Climate Change, 5(6), 588–595, 2015.

477   Kindler, R., Siemens, J.A.N., Kaiser, K., Walmsley, D.C., Bernhofer, C., Buchmann, N., Cellier, P.,

478   Eugster, W., Gleixner, G., GrŨNwald, T., Heim, A., Ibrom, A., Jones, S.K., Jones, M., Klumpp, K.,

479   Kutsch, W., Larsen, K.S., Lehuger, S., Loubet, B., McKenzie, R., Moors, E., Osborne, B.,

480   Pilegaard, K.I.M., Rebmann, C., Saunders, M., Schmidt, M.W.I., Schrumpf, M., Seyfferth, J.,

481   Skiba, U.T.E., Soussana, J.-F., Sutton, M.A., Tefs, C., Vowinckel, B., Zeeman, M.J.,

482   Kaupenjohann, M.: Dissolved carbon leaching from soil is a crucial component of the net

483   ecosystem carbon balance, Global Change Bio. 17, 1167–1185, 2011.

484   Lemma, B., Nilsson, I., Kleja, D.B., Olsson, M., Knicker, H.: Decomposition and substrate quality of

485   leaf litters and fine roots from three exotic plantations and a native forest in the southwestern

486   highlands of Ethiopia, Soil Bio. Bioch., 39, 2317–2328, 2007.

487   Liu, C.P., Sheu, B.H., 2003. Dissolved organic carbon in precipitation, throughfall, stemflow, soil

488   solution, and stream water at the Guandaushi subtropical forest in Taiwan, Forest Eco. Manag.,

489   172, 315–325, 2003.

490   Liu, W.J., Liu, W.Y., Li, J.T., Wu, Z.W., Li, H.M.: 2008. Isotope variations of throughfall, stemflow and

491   soil water in a tropical rain forest and a rubber plantation in Xishuangbanna, SW China, Hydrol.

492   Res., 39, 437–449, 2008.

493   McClain, M.E., Richey, J.E., Brandes, J.A., Pimentel, T.P.: Dissolved organic matter and

494   terrestrial-lotic linkages in the central Amazon basin of Brazil, Global Biogeochem. Cy., 11,

495   295–311, 1997.

496   McJannet, D., Wallace, J., Reddell, P.: Precipitation interception in Australian tropical rainforests: I.

497   Measurement of stemflow, throughfall and cloud interception, Hydrol. Process., 21, 1692–1702,

498   2007.

499   Montaño, N.M., Garcá-Oliva, F., Jaramillo, V.J.: Dissolved organic carbon affects soil microbial

500   activity and nitrogen dynamics in a Mexican tropical deciduous forest, Plant Soil, 295, 265–277,

501   2007.

502   Monteith, D.T., Stoddard, J.L., Evans, C.D., de Wit, H.A., Forsius, M., Høgåsen, T., Wilander, A.,

503   Skjelkvåle, B.L., Jeffries, D.S., Vuorenmaa, J., Keller, B., Kopácek, J., Vesely, J.: Dissolved

504   organic carbon trends resulting from changes in atmospheric deposition chemistry, Nature, 450,

505   537–540. 2007.

506   Neumann J., Matzner E.: Contribution of newly grown extramatrical ectomycorrhizal mycelium and

507   fine roots to soil respiration in a young Norway spruce site, Plant soil, 378(1–2): 73–82, 2014.

508   Park, J.H., Kalbitz, K., Matzner, E.: Resource control on the production of dissolved organic carbon

509   and nitrogen in a deciduous forest floor, Soil Bio. Bioche., 34, 1391–1391, 2002..

510   Qiao, N., Schaefer, D., Blagodatskaya, E., Zou, X., Xu, X., Kuzyakov, Y.: Labile carbon retention

511   compensates for CO_2 released by priming in forest soils, Global Change Biol., 20(6): 1943–1954,

512   2014..

513   Reichstein, M., Rey, A., Freibauer, A., Tenhunen, J., Valentini, R., Banza, J., Casals, P., Cheng, Y.F.,

514   Grunzweig, J.M., Irvine, J., Joffre, R., Law, B.E., Loustau, D., Miglietta, F., Oechel, W., Ourcival,

515   J.M., Pereira, J.S., Peressotti, A., Ponti, F., Qi, Y., Rambal, S., Rayment, M., Romanya, J., Rossi,

516   F., Tedeschi, V., Tirone, G., Xu, M., Yakir, D.: Modeling temporal and large-scale spatial

517   variability of soil respiration from soil water availability, temperature and vegetation productivity

518   indices, Global Biogeoche. Cy., 17, DOI: 10.1029/2003GB002035,2003.

519   Sanderman, J., Amundson, R.: A comparative study of dissolved organic carbon transport and

520   stabilization in California forest and grassland soils, Biogeochemistry, 89, 309–327, 2008.

521   Schrumpf, M., Zech, W., Lehmann, J., Lyaruu, H.V.C.: TOC, TON, TOS and TOP in rainfall,

522   throughfall, litter percolate and soil solution of a montane rainforest succession at Mt. Kilimanjaro,

523   Tanzania, Biogeochemistry, 78, 361–387, 2006.

524   Schwendenmann, L., Veldkamp, E.: The role of dissolved organic carbon, dissolved organic nitrogen,

525   and dissolved inorganic nitrogen in a tropical wet forest ecosystem, Ecosystems, 8, 339–351,

526   2005..

527   Sha, L.Q., Zheng, Z., Tang, J.W., Wang, Y.H., Zhang, Y.P., Cao, M., Wang, R., Liu, G.G., Wang, Y.S.,

528   Sun, Y.: Soil respiration in tropical seasonal rain forest in Xishuangbanna, SW China, Science in

529   China Series D-Earth Sciences, 48, 189–197, 2005(In Chinese).

530   Shi L.L.: Soil Microbial Community in Forest Ecosystem as Revealed by Molecular Techniques

531   —diversity pattern, maintenance mechanism, and the response to disturbance, A Dissertation

532   Submitted to University of Chinese Academy of Sciences, In partial fulfillment of the requirement

533   Doctor of Philosophy, 2014 (In Chinese).

534 Sowerby, A., Emmett, B.A., Williams, D., Beier, C., Evans, C.D.: The response of dissolved organic

535 carbon (DOC) and the ecosystem carbon balance to experimental drought in a temperate

536 shrubland, Eur. J. Soil Sci., 61, 697–709, 2010.

537 Stephan, S., Karsten, K., Egbert, M.: Controls on the dynamics of dissolved organic carbon and

538 nitrogen in a Central European deciduous forest, Biogeochemistry, 55, 327–349, 2001.

539 Tan, Z., Zhang, Y., Yu, G., Sha, L., Tang, J., Deng, X., Song, Q.: Carbon balance of a primary tropical

540 seasonal rain forest, J. Geophys. Res, 115 (D4), DOI: 10.1029/2009JD012913, 2010.

541 Tang, J.W., Cao, M., Zhang, J.H., Li, M.H., Litterfall production, decomposition and nutrient use

542 efficiency varies with tropical forest types in Xishuangbanna, SW China: a 10-year study, Plant

543 soil, 335, 271–288, 2010.

544 Tang, Y.L., Deng, X.B., Li, Y.W., Zhang, S.B.: Research on the difference of soil fertility in the

545 different forest types in Xishuangbanna, Journal of Anhui Agricultural Sciences, 35,

546 779–781,2007 (In Chinese).

547 Tomè, E., Ventura, M., Folegot, S., Zanotelli, D., Montagnani, L., Mimmo, T., Tonon, G., Tagliavini, M.,

548 Scandellari, F.: Mycorrhizal contribution to soil respiration in an apple orchard. Appl. Soil.

549 ecol.,, 101, 165–173, 2016.

550 Wu, Y., Yang, X., Yu, G.: Seasonal fluctuation of soil microbial biomass carbon and its influence factors

551 in two types of tropical rainforests, Ecology and Environmental Sciences, 18, 658–663, 2009 (In

552 Chinese).

553 Yakov, K.: Priming effects: Interactions between living and dead organic matter. Soil Bio. Biochem. 42,

554 1363–1371, 2010.

555 Zhang, Y., Tan, Z., Song, Q., Yu, G., Sun, X.: Respiration controls the unexpected seasonal pattern of

556   carbon flux in an Asian tropical rain forest, Atmos. Environ. 44, 3886–3893, 2010.

557   Zheng, Z.M., Yu, G.R., Fu, Y.L., Wang, Y.S., Sun, X.M., Wang, Y.H.: Temperature sensitivity of soil

558   respiration is affected by prevailing climatic conditions and soil organic carbon content: A

559   trans-China based case study, Soil Bio. Biochem., 41, 1531–1540, 2009.

560   Zimmermann, A., Wilcke, W., Elsenbeer, H.: Spatial and temporal patterns of throughfall quantity and

561   quality in a tropical montane forest in Ecuador, J. Hydrol. 343, 80–96, 2007.

562

Table legends

Table 1 The interception rate of the water between hydrological processes in the tropical rainforest at Xishuangbanna southwest China

Table 2 DOC δ^{13}C dynamics along the hydrological processes (R, rainfall, TF, throughfall, LL, litter leachate) and the δ^{13}C in leaves, litter, and surface soil in the tropical rainforest at Xishuangbanna, southwest China

Table 3 Results of a regression analysis of the weekly water flux, DOC flux, soil respiration (SR), and heterotrophic respiration (HR) along the hydrological processes (TF, throughfall, LL, litter leachate) in the tropical rainforest in Xishuangbanna, southwest China.

Figure captions

Figure 1 Amount of water (A) and DOC flux along the hydrological processes in the tropical rainforest at Xishuangbanna, southwest China.

Figure 2 Dynamics of soil respiration (SR) and heterotrophic respiration (HR) (a) and soil temperature at 5cm and soil water content at 10cm (b) in the tropical rainforest at Xishuangbanna, southwest China. The shaded area indicates the rainy season.

579

580 Table 1

Interception（%）		Annual	Rainy season（%）	Dry season
Water flux	Between TF and P	53.9±11.7	43.1±2.7	41.3±14.8
	Between LL and TF	33.9±6.6	33.9±9.8	34.1±27.6
	Between SW20cm and LL	63.8±8.0	62.2±15.1	81.6±23.3
DOC flux	Between TF and R	137.0±19.9	182.0±16.0	170.8±7.8
	Between LL and TF	1.1±17.0	16.1±9.4	12.7±4.3
	Between SW20cm and LL	-96.7±4.4	-93.9±2.6	-94.4±1.2

581 P indicates rainfall, TF indicates throughfall, LL indicates litter leachate, SW20 indicates soil water at a

582 depth of 20 cm.

583   Table2
584

Season	P	TF	LL	Soil water (0–20 cm)	Leaves	Litter	Soil (0–20 cm)
				‰			
Rainy season	−23.9±3.3^a	−28.7±1.7^{bc}	−28.1±2.7^{bc}	−23.9±1.6^a *	−32.4±0.6^d	−30.4±0.2^{cd}	−27.3±0.1^b
Dry season	−23.8±1.3^a	−29.1±1.6^{bc}	−28.1±1.5^{bc}	−27.1±2.2^b	−32.5±0.5^d	−30.2±0.1^{cd}	−27.3±0.1^{bc}

585   P indicates rainfall, TF indicates throughfall, LL indicates litter leachate, SW20 indicates soil water at a

586   depth of 20 cm.

587   Different superior letters indicate significant differences between the treatments according to Lsd test

588   ($P < 0.05$).

589   *indicates the significant seasonal difference according to independent sample t test ($p < 0.1$)

590

591 Table 3

		SR				HR			
		a	b	R^2	p	a	b	R^2	p
DOC flux	T	0.56	0.54	0.987	<0.001	0.46	0.64	0.982	<0.001
	SWC	0.65	0.41	0.558	<0.001	0.53	0.52	0.568	<0.001
	P	2.31	-1.17	0.423	<0.001	1.86	-0.74	0.425	<0.001
	TF	2.36	-1.25	0.429	<0.001	1.91	-0.83	0.413	<0.001
	LL	2.71	-1.57	0.355	<0.001	2.21	-1.10	0.366	<0.001
	SW20	3.57	-2.23	0.227	<0.001	2.91	-1.62	0.240	<0.001
	LL-SW20	2.66	-1.53	0.352	<0.001	2.17	-1.07	0.363	<0.001
Water flux	P	2.42	-1.35	0.323	<0.001	1.96	-0.92	0.331	<0.001
	TF	2.55	-1.44	0.316	<0.001	2.06	-0.99	0.323	<0.001
	LL	3.02	-1.83	0.301	<0.001	2.46	-1.31	0.312	<0.001
	SW20	3.70	-2.34	0.166	<0.001	3.02	-1.71	0.178	<0.001
	LL-SW20	2.64	-1.54	0.257	<0.001	2.14	-1.08	0.267	<0.001

592 Equations used to calculate the sensitivity indices: sensitivity index = a, where b is the constant of the

593 regression equation for standardized soil respirations, and soil temperature, soil water content, water

594 flux, and DOC flux: $Y = aX + b$, where Y is the standardized soil respiration rate, and X is standardized

595 soil temperature, soil water content, water flux, or DOC flux.

596 T indicates soil temperature at a depth of 5 cm, SWC indicates soil water content, TF indicates

597 throughfall, LL indicates litter leachate, SW20 indicates soil water at a depth of 20 cm, LL- SW20

598 indicates the difference between litter leachate and soil water at a depth of 20 cm.
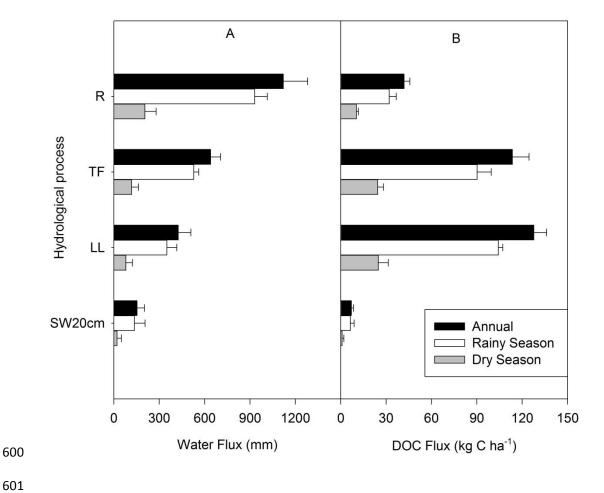
599   Figure 1

600

601

602

603   Figure 2

604

605