Supplement of

Soil CO₂ efflux from two mountain forests in the eastern Himalayas, Bhutan: components and controls

Norbu Wangdi et al.

Correspondence to: Norbu Wangdi (norwangs@gmail.com)

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#### Install package to read .xls files
install.packages('XLConnect')
library('XLConnect')

#### Set working directory
setwd("D:/Buthan/FinalVersion")

#### Read continuous soil climate data

## Broadleaved forest

BF = readWorksheet(loadWorkbook('SoilClimate_BroadleavedForest.xlsx'),sheet = 1)

## Mixed forest

MF = readWorksheet(loadWorkbook('SoilClimate_MixedForest.xlsx'),sheet = 1)

#### Variable description:

# site: BF = broadleaved forest; MF = mixed forest
# VWC_5cm: volumetric soil water content (vol.%) measured in 5 cm depth
# VWC_20cm: volumetric soil water content (vol.%) measured in 20 cm depth
# T_5cm: soil temperature (°C) measured in 5 cm depth
# T_20cm: soil temperature (°C) measured in 20 cm depth

# All values are daily mean values

#### Set parameters

##### Temperature response function (Equation 1)

##### Broadleaved forest

# Forest floor litter

BF_Lit_T_b0 = 0.265
BF_Lit_T_b1 = 0.0793

# Mineral soil

BF_Min_T_b0 = 0.0961
BF_Min_T_b1 = 0.0828

##### Mixed forest

# Forest floor litter

MF_Lit_T_b0 = 0.548
MF_Lit_T_b1 = 0.0645

# Mineral soil
MF_Min_T_b0 = 0.0701
MF_Min_T_b1 = 0.0808

### Moisture response function (Equation 3)

## Broadleaved forest

# Mineral soil only

BF_M_b0 = 0.0080456
BF_M_b1 = 0.01194
BF_M_b2 = -0.00012588

## Mixed forest

# Mineral soil only

MF_M_b0 = -0.086751
MF_M_b1 = 0.017487
MF_M_b2 = -0.00020757

### Soil moisture (vol.%) of samples during first incubations (see Table 2)

## Broadleaved forest

# Forest floor litter

BF_M_Inc_Lit = 46

# Mineral soil

BF_M_Inc_Min = 35
## Mixed forest

# Forest floor litter

MF_M_Inc_Lit = 46

# Mineral soil

MF_M_Inc_Min = 33

### Soil carbon stocks (kg/m²) (see Table 1)

## Broadleaved forest

# Annual litter input (proxy for litter C stock)

BF_C_Lit = 0.34

# Mineral soil C stocks in 0-10 cm depth (data from 4 soil pits)

BF_C_Min_0_10 = c(6.04, 7.00, 5.46, 3.71)

# Mineral soil C stocks in 10-20 cm depth (data from 4 soil pits)

BF_C_Min_10_30 = c(3.69, 4.01, 3.04, 3.10)

## Mixed forest

# Annual litter input (proxy for litter C stock)
MF_C_Lit = 0.35

# Mineral soil C stocks in 0-10 cm depth (data from 4 soil pits)

MF_C_Min_0_10 = c(5.34, 6.71, 4.83, 7.28)

# Mineral soil C stocks in 10-20 cm depth (data from 4 soil pits)

MF_C_Min_10_30 = c(8.53, 7.46, 6.16, 9.91)

#### Modelling heterotrophic respiration (Rh) for each layer

## Broadleaved forest

BF_matrix = matrix(nrow=nrow(BF), ncol=4)  # empty matrix

BF_matrix_mineral = matrix(nrow=nrow(BF), ncol=4)

BF_matrix_mineral_10_30 = matrix(nrow=nrow(BF), ncol=4)

for (i in 1:nrow(BF)) {
    for (j in 1:4) {

        BF_matrix[i,j] =

        # Forest floor litter

        (((BF_Lit_T_b0 * exp(BF_Lit_T_b1 * BF$T_5cm[i])) * # Modell Rh with Temp
BF_C_Lit * # Multiply by C stocks

$$((\text{BF}_M\_b0 + \text{BF}_M\_b1 \times \text{BF}_VWC\_5cm[i] + \text{BF}_M\_b2 \times (\text{BF}_VWC\_5cm[i] \times 2) / \# \text{Correct for field moisture})$$

$$((\text{BF}_M\_b0 + \text{BF}_M\_b1 \times \text{BF}_M\_Inc\_Lit + \text{BF}_M\_b2 \times (\text{BF}_M\_Inc\_Lit \times 2))$$

+ 

# Mineral soil 0-10 cm depth

$$((\text{BF}_\text{Min}\_T\_b0 \times \exp(\text{BF}_\text{Min}\_T\_b1 \times \text{BF}_T\_5cm[i])) \times$$

$$\text{BF}_C\_\text{Min\_0\_10}[j] \times$$

$$((\text{BF}_M\_b0 + \text{BF}_M\_b1 \times \text{BF}_VWC\_5cm[i] + \text{BF}_M\_b2 \times (\text{BF}_VWC\_5cm[i] \times 2) / \text{BF}_M\_b0 + \text{BF}_M\_b1 \times \text{BF}_M\_Inc\_Min + \text{BF}_M\_b2 \times (\text{BF}_M\_Inc\_Min \times 2))$$

+ 

# Mineral soil 10-30 cm depth

$$((\text{BF}_\text{Min}\_T\_b0 \times \exp(\text{BF}_\text{Min}\_T\_b1 \times \text{BF}_T\_20cm[i])) \times$$

$$\text{BF}_C\_\text{Min\_10\_30}[j] \times$$

$$((\text{BF}_M\_b0 + \text{BF}_M\_b1 \times \text{BF}_VWC\_20cm[i] + \text{BF}_M\_b2 \times (\text{BF}_VWC\_20cm[i] \times 2) / \text{BF}_M\_b0 + \text{BF}_M\_b1 \times \text{BF}_M\_Inc\_Min + \text{BF}_M\_b2 \times (\text{BF}_M\_Inc\_Min \times 2))$$
BF_matrix_mineral[i,j] =

# Mineral soil 0-10 cm depth

(((BF_Min_T_b0 * exp(BF_Min_T_b1 * BF$T_5cm[i])) * 

BF_C_Min_0_10[j] * 

((BF_M_b0 + BF_M_b1 * BF$VWC_5cm[i] + BF_M_b2 * BF$VWC_5cm[i]^2) /
(BF_M_b0 + BF_M_b1 * BF_M_Inc_Min + BF_M_b2 * BF_M_Inc_Min^2)))

+ 

# Mineral soil 10-30 cm depth

(((BF_Min_T_b0 * exp(BF_Min_T_b1 * BF$T_20cm[i])) * 

BF_C_Min_10_30[j] * 

((BF_M_b0 + BF_M_b1 * BF$VWC_20cm[i] + BF_M_b2 * BF$VWC_20cm[i]^2) /
(BF_M_b0 + BF_M_b1 * BF_M_Inc_Min + BF_M_b2 * BF_M_Inc_Min^2)))

BF_matrix_mineral_10_30[i,j] =

# Mineral soil 10-30 cm depth
((BF_Min_T_b0 * exp(BF_Min_T_b1 * BF$T_20cm[i]))) *

BF_C_Min_10_30[j] *

((BF_M_b0 + BF_M_b1 * BF$VWC_20cm[i] + BF_M_b2 * BF$VWC_20cm[i]^2) /

(BF_M_b0 + BF_M_b1 * BF_M_Inc_Min + BF_M_b2 * BF_M_Inc_Min ^ 2)))

# Calculate mean values in µmol CO2 kgC^-1 sec^-1

BF$Rh = apply(BF_matrix, 1, FUN = mean)

BF$Rh_Min = apply(BF_matrix_mineral, 1, FUN = mean)

BF$Rh_Min_10_30 = apply(BF_matrix_mineral_10_30, 1, FUN = mean)

## Mixed forest

MF_matrix = matrix(nrow=nrow(MF), ncol=4)

MF_matrix_mineral = matrix(nrow=nrow(MF), ncol=4)

MF_matrix_mineral_10_30 = matrix(nrow=nrow(MF), ncol=4)
for (i in 1:nrow(MF)) {

for (j in 1:4) {

MF_matrix[i,j] =

# Forest floor litter

(((MF_Lit_T_b0 * exp(MF_Lit_T_b1 * MF$T_5cm[i]))) * # Modell Rh with Temp

MF_C_Lit * # Multiply by C stocks

(((MF_M_b0 + MF_M_b1 * MF$VWC_5cm[i] + MF_M_b2 * MF$VWC_5cm[i] ^ 2) / # Correct for
field moisture

(MF_M_b0 + MF_M_b1 * MF_M_Inc_Lit + MF_M_b2 * MF_M_Inc_Lit ^ 2)))

+

# Mineral soil 0-10 cm depth

(((MF_Min_T_b0 * exp(MF_Min_T_b1 * MF$T_5cm[i]))) *

MF_C_Min_0_10[j] *

(((MF_M_b0 + MF_M_b1 * MF$VWC_5cm[i] + MF_M_b2 * MF$VWC_5cm[i] ^ 2) /

(MF_M_b0 + MF_M_b1 * MF_M_Inc_Min + MF_M_b2 * MF_M_Inc_Min ^ 2)))

+}
# Mineral soil 10-30 cm depth

\[
((\text{MF}_{\text{MinT}}_{b0} \ast \exp(\text{MF}_{\text{MinT}}_{b1} \ast \text{MF}_T_{20cm[i]})) \ast \text{MF}_{\text{CMin}_{10\_30}}[j] \ast \\
((\text{MF}_{M}b0 + \text{MF}_{M}b1 \ast \text{MF}_{VWC_{20cm}}[i] + \text{MF}_{M}b2 \ast \text{MF}_{VWC_{20cm}}[i]^2) / \\
(\text{MF}_{M}b0 + \text{MF}_{M}b1 \ast \text{MF}_{\text{MInc\_Min}} + \text{MF}_{M}b2 \ast \text{MF}_{\text{MInc\_Min}}^2)))
\]

\[
\text{MF\_matrix\_mineral}[i,j] =
\]

# Mineral soil 0-10 cm depth

\[
(((\text{MF}_{\text{MinT}}_{b0} \ast \exp(\text{MF}_{\text{MinT}}_{b1} \ast \text{MF}_T_{5cm[i]})) \ast \text{MF}_{\text{CMin}_{0\_10}}[j] \ast \\
((\text{MF}_{M}b0 + \text{MF}_{M}b1 \ast \text{MF}_{VWC_{5cm}}[i] + \text{MF}_{M}b2 \ast \text{MF}_{VWC_{5cm}}[i]^2) / \\
(\text{MF}_{M}b0 + \text{MF}_{M}b1 \ast \text{MF}_{\text{MInc\_Min}} + \text{MF}_{M}b2 \ast \text{MF}_{\text{MInc\_Min}}^2)))
\]

+ 

# Mineral soil 10-30 cm depth

\[
(((\text{MF}_{\text{MinT}}_{b0} \ast \exp(\text{MF}_{\text{MinT}}_{b1} \ast \text{MF}_T_{20cm[i]})) \ast \\
((\text{MF}_{M}b0 + \text{MF}_{M}b1 \ast \text{MF}_{VWC_{20cm}}[i] + \text{MF}_{M}b2 \ast \text{MF}_{VWC_{20cm}}[i]^2) / \\
(\text{MF}_{M}b0 + \text{MF}_{M}b1 \ast \text{MF}_{\text{MInc\_Min}} + \text{MF}_{M}b2 \ast \text{MF}_{\text{MInc\_Min}}^2)))
\]
MF_C_Min_10_30[j] * 

((MF_M_b0 + MF_M_b1 * MF_VWC_20cm[i] + MF_M_b2 * MF_VWC_20cm[i]^2) / 
(MF_M_b0 + MF_M_b1 * MF_M_Inc_Min + MF_M_b2 * MF_M_Inc_Min ^ 2))))

MF_matrix_mineral_10_30[i,j] =

# Mineral soil 10-30 cm depth

((MF_Min_T_b0 * exp(MF_Min_T_b1 * MF_T_20cm[i])) * 
MF_C_Min_10_30[j] * 

((MF_M_b0 + MF_M_b1 * MF_VWC_20cm[i] + MF_M_b2 * MF_VWC_20cm[i]^2) / 
(MF_M_b0 + MF_M_b1 * MF_M_Inc_Min + MF_M_b2 * MF_M_Inc_Min ^ 2))))

}

# Calculate mean values in µmol CO2 kgC^-1 sec^-1

MF$Rh = apply(MF_matrix, 1, FUN = mean)

MF$Rh_Min = apply(MF_matrix_mineral, 1, FUN = mean)

MF$Rh_Min_10_30 = apply(MF_matrix_mineral_10_30, 1, FUN = mean)