SPONSORED BY THE Federal Ministry of Education and Research

FONA Research for Sustainable Development BMBF

SUSTAINABLE LAND MANAGEMENT

SURUMER

UNIVERSITY OF HOHENHEIM

Improving the Model Prediction of Soil Temperature under Rubber Plantations

Xiaomin Yu[1], Gerhard Langenberger[2], Georg Cadisch[2], Sergey Blagodatsky[2]

1 Institute of Farm Management; **2** Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany

Background

The expansion of rubber plantations in South-East Asia has been the major driving force for deforestation and forest degradation, coupled with dramatic losses of ecosystem functions and losses of soil organic carbon. An important reason for the losses of SOC is soil organic matter decomposition, which is mainly influenced by the soil temperature. As directly measured soil temperatures are often not available, modelling soil temperature with easy-to-get data has gained much attention.

Objective

To calibrate and further develop a soil temperature model based on a hybrid (empirical-physical) model proposed by Kang et al. (2000) , for its application in tropical rubber plantations.

Methods

The study is within the framework of the SURUMER project (*https://surumer.uni-hohenheim.de*). Data were collected from two stations at Naban Nature Reserve (22° 04' - 22° 17'N, 100° 32' - 100° 44'E) in Xishuangbanna, Southwest China, namely Naban Station and Banqiandi Station **(Fig. 1).**

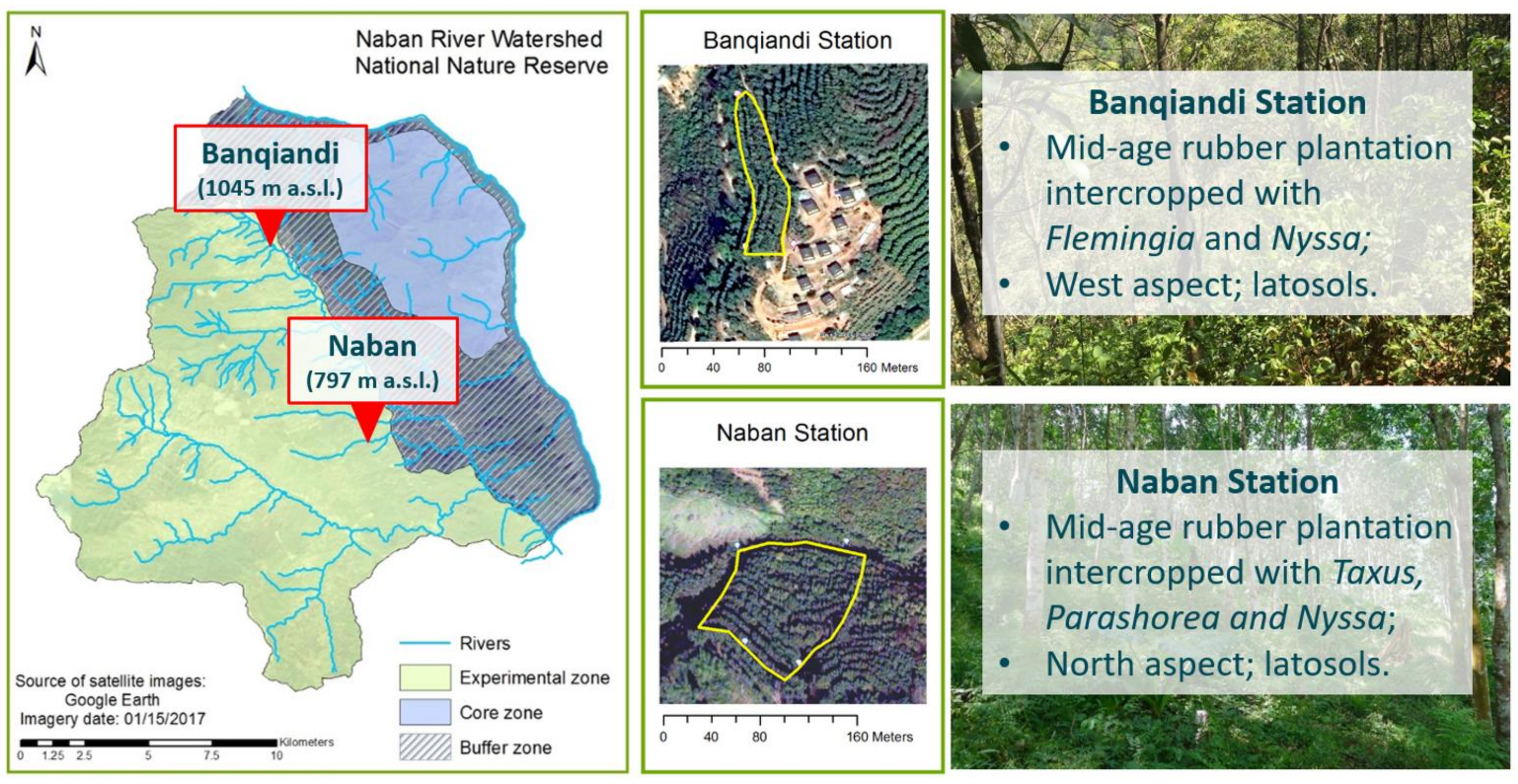


***Figure 1** The location and description of Naban and Banqiandi Station.*

Soil temperature data at 10/20/40 cm depth, close-to-ground air temperature (20 cm height) and reference air temperature data were collected with TinyTag and HOBO loggers from in total nine sites at Naban and Banqiandi Station during 17 to 24 months. Leaf area index (LAI) and litter fall data in rubber plantations were available within the SURUMER database.

Model Development

"The Original Model" used as starting point for model improvement was a hybrid soil temperature model proposed by Kang et al. (*Forest Ecology and Management (2000), 136: 173–184*) **(Fig. 2)**. The model integrates heat transfer physics with empirical relations between air and soil temperature, taking into consideration the effects of canopy and ground litter on heat attenuation. Input data needed are daily air temperature and LAI.

When air temperature A_j > soil temperature T_{j-1} (z):

Extinction coefficient k=0.45

$$T_j(z) = T_{j-1}(z) + [A_j - T_{j-1}(z)] \cdot \exp\left[-z\left(\frac{\pi}{k_s p}\right)^{1/2}\right] \cdot \exp[-k(LAI_j + Litter_j)]$$

$$Litter_j = Litter_{j-1} \cdot e^{-0.01}$$

$$Litter_1 = \frac{1}{2} \cdot LAI_{max}$$

Soil thermal diffusivity K_s=0.005 cm^2/s

The period of annual variation p=(365*24*60*60) s

When air temperature A_j ≤ soil temperature T_{j-1} (z):

$$T_j(z) = T_{j-1}(z) + [A_j - T_{j-1}(z)] \cdot \exp\left[-z\left(\frac{\pi}{k_s p}\right)^{1/2}\right] \cdot \exp[-k \cdot Litter_j]$$

***Figure 2** "The Original model" developed by Kang et al. (2000)*

Two stages of model development (**Fig. 3**) were performed, resulting in two ready-to-use model packages depending on data availability.

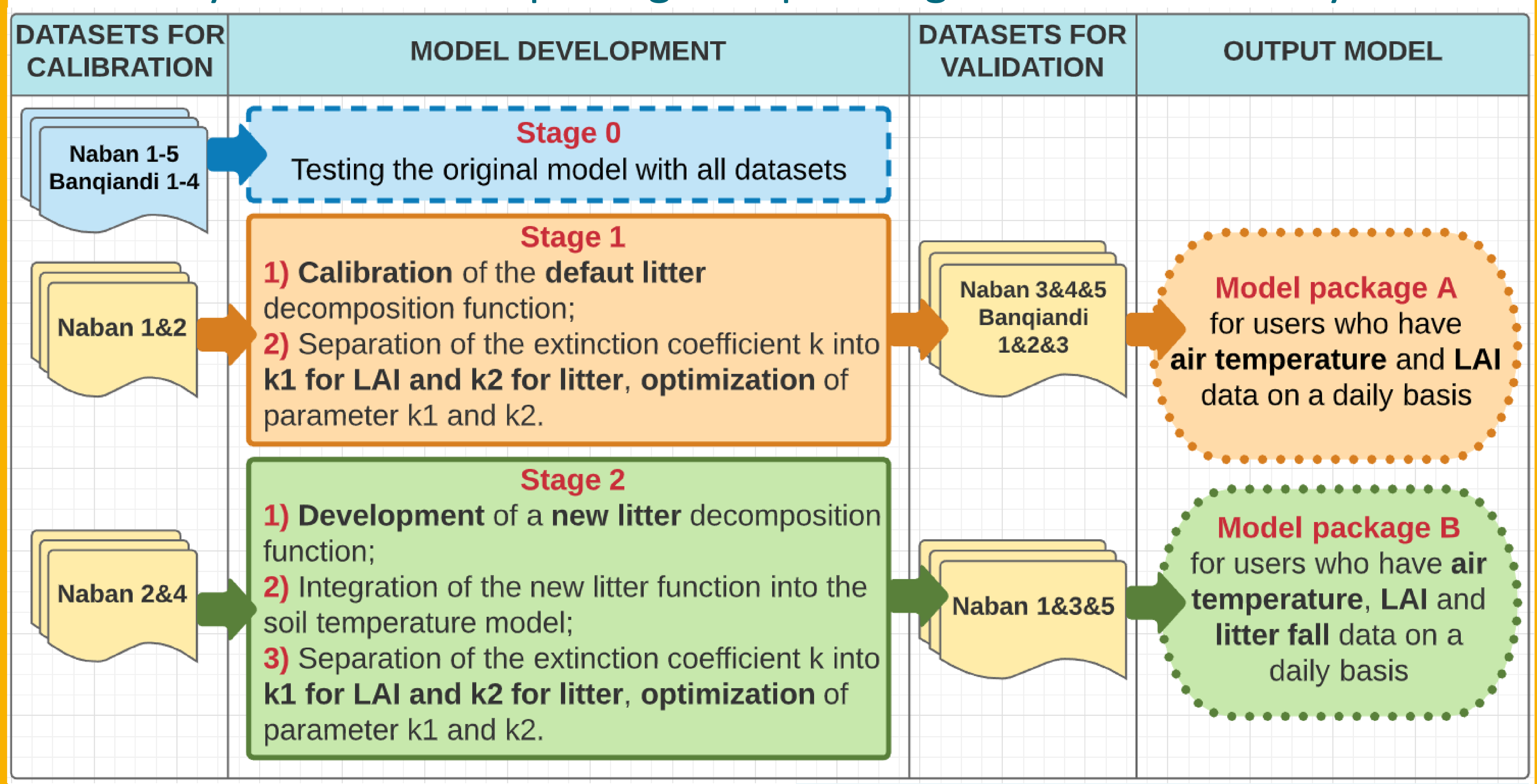


***Figure 3** Roadmap of the model development.*

Statistics selected for model performance evaluation were Nash-Sutcliffe efficiency (NSE) and RMSE-observations standard deviation ratio (RSR).

Results

The heat transfer through canopy and ground litter was modelled separately as compare to the original model using two proposed model packages. Statistical analysis performed after calibration and validation of both model packages proved that new approach out-performed the original model (**Fig. 4**).

When $A_j > T_{j-1}$ (z): $\exp[-k_1 \cdot LAI_j - k_2 \cdot Litter_j]$

When $A_j \le T_{j-1}$ (z): $\exp[-k_2 \cdot Litter_j]$

Package A

- $Litter_j = Litter_{j-1} \cdot e^{-0.01}$

when j=60, $Litter_{60} = LAI_{max}$

- k_1=0.30, k_2=0.60

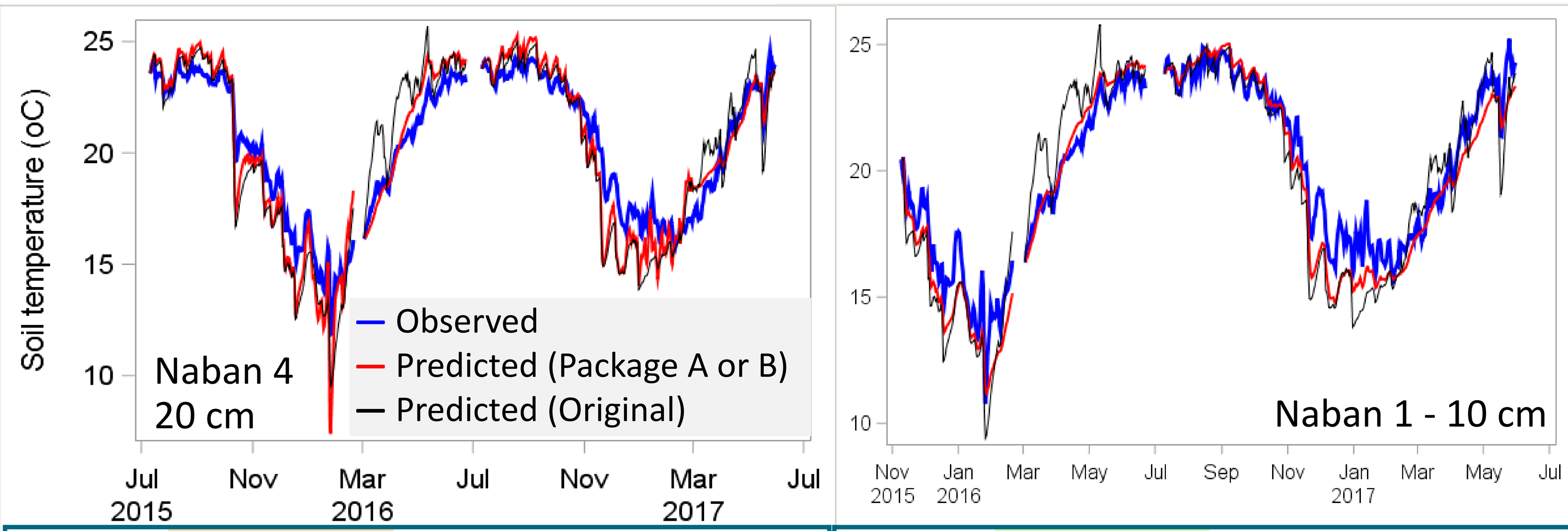
Package B

- $Litter_j = (Litter_{j-1} + Litterfall_j) \cdot e^{-(V_C \cdot r_{T20cm}) \cdot t}$

r_{T20cm}: temperature correction factor;

V_C: constant factor; **t**=1/365

- k_1 = 0.30, k_2 =0.35



	Package A	Original	Δ
NSE	0.86	0.78	+ 0.08
RSR	0.37	0.47	- 0.10

	Package B	Original	Δ
NSE	0.91	0.82	+ 0.09
RSR	0.30	0.43	- 0.13

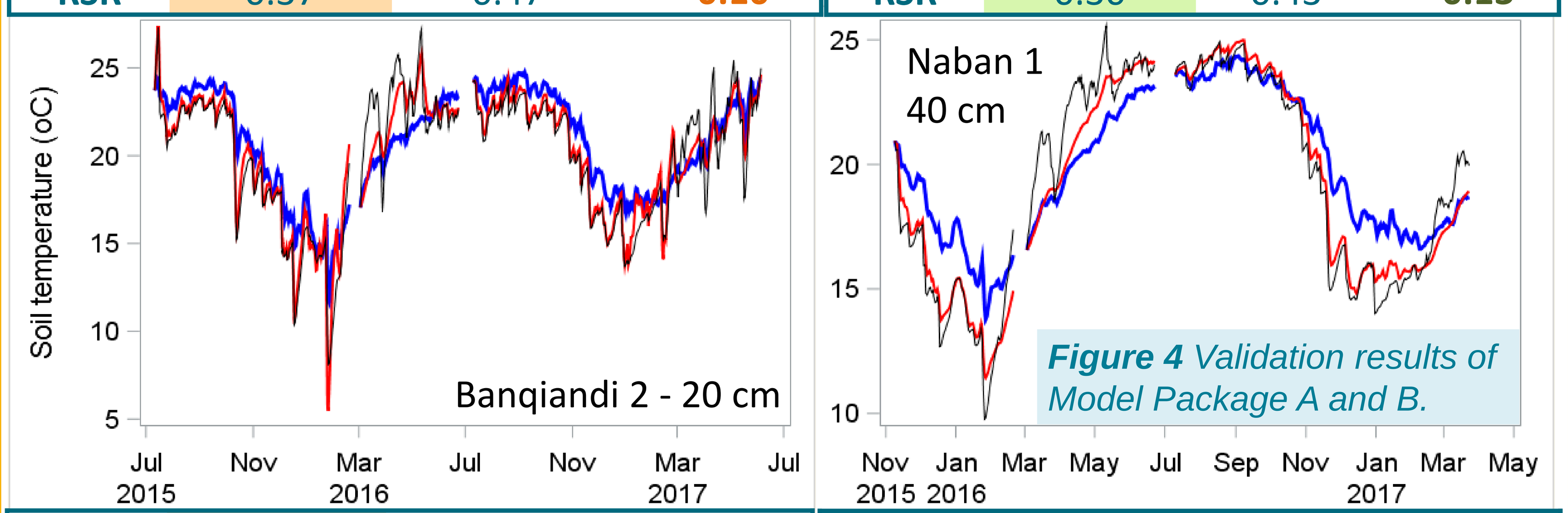


***Figure 4** Validation results of Model Package A and B.*

	Package A	Original	Δ
NSE	0.73	0.56	+ 0.17
RSR	0.52	0.66	- 0.15

	Package B	Original	Δ
NSE	0.72	0.48	+ 0.23
RSR	0.53	0.72	- 0.18

Conclusions

Two ready-to-use soil temperature models are validated for tropical rubber plantations and can be selected by model users depending on the data availability. Both models yield satisfying simulation results.

Corresponding Author

Xiaomin Yu, Institute of Farm Management, Faculty of Agricultural Sciences, University of Hohenheim, 70593 Stuttgart, Germany

Email: xiaomin.yu@uni-hohenheim.de

www.sustainable-landmanagement.net

www.surumer.uni-hohenheim.de

September 2019