DynACof Process-based Model Parameterization and Validation for Robusta Coffee

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INTRODUCTION

- Most coffee is produced from Arabica (60%) and Robusta (40%) (Kouadio et al., 2021).
- Brazil, Vietnam, Indonesia, and Colombia account for about 68% of the global coffee market. Vietnam leads global Robusta production (Gokavi et al., 2020).
- Over 90% of coffee is grown in developing countries, while about 75% is consumed in developed countries (ICO, 2018).
- Suitable climate for both species is expected to decline by 50% by 2050. Brazil has already experienced a 20% reduction in suitable coffee-growing areas since 1974 (Koh et al., 2020).
- Robusta is generally more resilient under stress conditions, but climate change impacts have also been observed in Vietnam (Roonprapant et al., 2021).
- Several models have been developed to propose climate adaptation strategies, but none have focused on Robusta coffee under tree shade (Faraz et al., 2023).
- Therefore, In this study DynACof model was modified to simulate Robusta species in an agroforestry system.

OBJECTIVE

1. Propose the use of DynACof model to simulate crop yield and growth for Robusta coffee
2. Parameterize and validate the model for Robusta coffee and explore differences with Arabica Test the model performance for Robusta coffee under different pedo-climatic characteristics
3. Assess the coffee parameters influencing DynACof model performance.
4. Assess DynACof model performance through statistical indices

Table 1. The parameterisation of the coffee model

Parameters	Description	Unite
SLA	Specific leaf area	m²/kg
Wleaf	leaf width	m
DELM	Max leaf carbon demand	gC/ plant day
kres	Maximum carbon proportion extracted from reserves mass per day	0-1
F_buds1	Bud development stage 1	Degree day
F_buds2	Bud development stage 2	Degree day
a_bud	Parameter for bud initiation	Bud per day
F_Tffb	Time of first floral buds	Degree day
a_p	Parameter for bud dormancy break	1
b_p	Parameter for bud dormancy break	1
Max_Bud_Break	Max number of nodes that can break dormancy daily	Buds/node
F_over	Duration until fruit stage 5 overripe in the soil	Degree day
u_log	Parameters for the logistic fruit growth pattern (Fruit Maturation/2)	Degree day
FtS	Fruit to seed ratio	g/g

Table 2. Model calibration was based on selected parameters in the coffee mode

Parameters	Default Value	Range for Testing	Value after Calibration
SLA	11	11-13,	12.97
Wleaf	0.06	0.09-0.12	0.12
DELM	15	15-19	18.8
Kres	0.06	0.06-0.11	0.087
F_buds1	720	720-840	725
F_buds2	2562	2562-2690	2627
a_bud	0.009	0.009-0.012	0.0112
F_Tffb	4500	4500-5500	5059
a_p	3	3-4.78	3.46
b_p	1.9	1.9-2.1	2
Max_Bud_Break	16	16-19	17
F_over	3404	3404-3600	3459
u_log	1480	1480-1600	1559
FtS	0.63	0.63-0.7	0.686

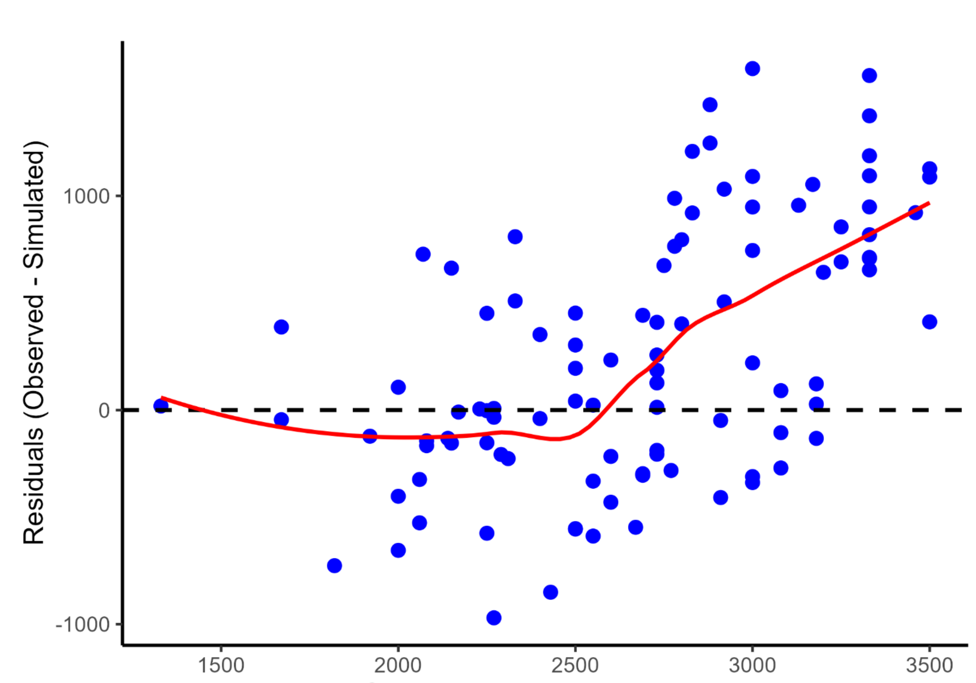

Figure 4. The visual presentation of residual distribution

RESULTS

Table 3. Model performance in predicting Robusta coffee bean yield in training and validation districts

	Districts	R2	D-index	nRMSE (%)
Training	Dak Song	0.56	0.84	7.62
	Dak Glang	0.20	0.69	13.71
	Lagari	0.42	0.62	36.72
	Dak Doa	0.08	0.49	20.49
	Lam Ha	0.40	0.51	32.78
	Duc Trong	0.53	0.48	33.38
	Krong Nang	0.59	0.81	12.09
Validation	Bao Loc	0.26	0.57	25.06
	Chu Prong	0.31	0.67	18.40
	Krong Buk	0.52	0.58	20.63

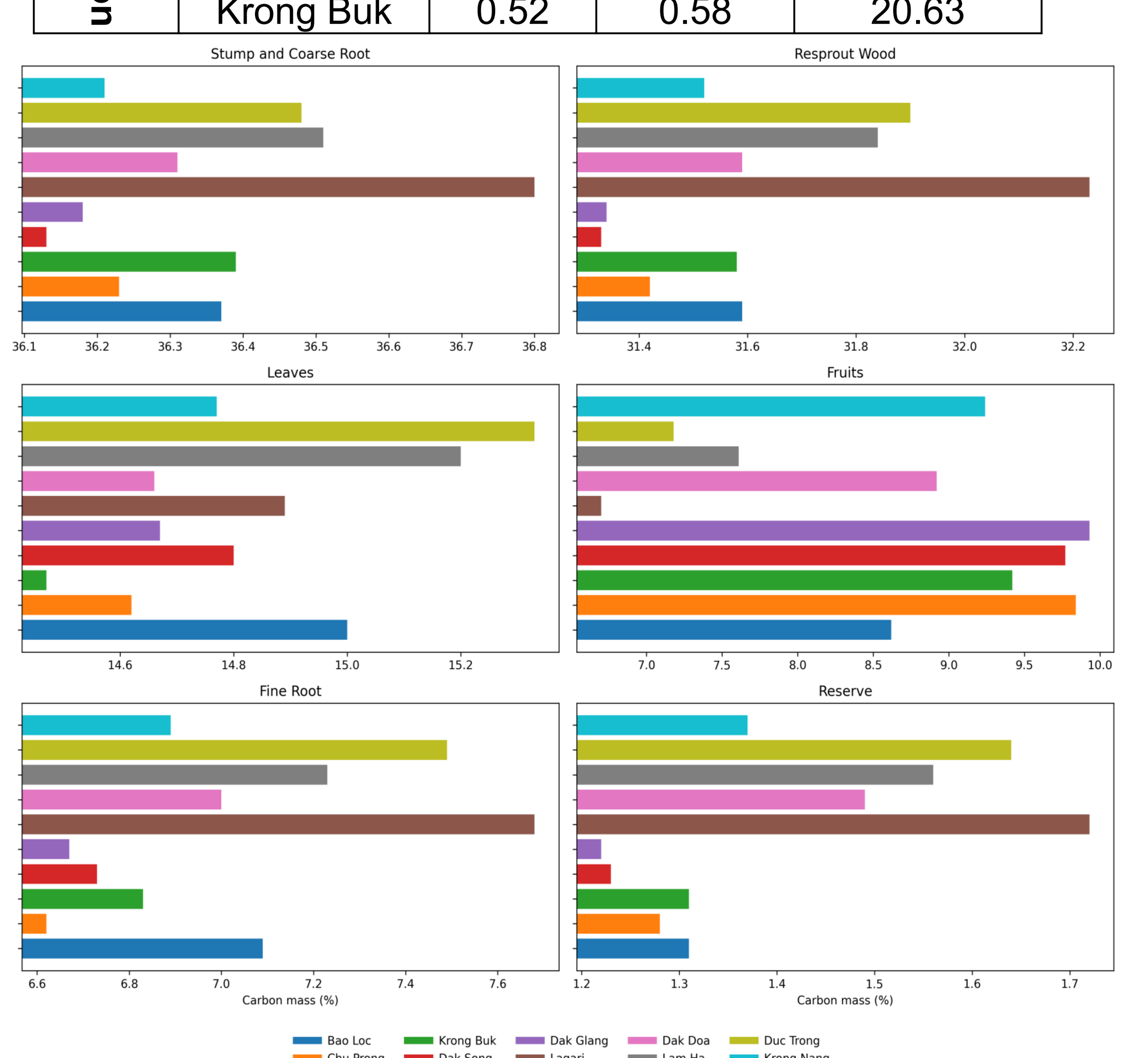

Figure 3. Carbon mass in percentage in various coffee plant organs

METHODOLOGY

Study Region: Vietnam

Dataset

1. Reference bean yield data

Robusta bean yield was used from 2007 to 2017 (University of Queensland, Australia)

2. Climate and Soil data

Reanalysis dataset was used from 2005 to 2017 (https://cds.Climate.Copernicus.Eu).

Temperature and rainfall data were downloaded from figshare (https://figshare.Com).

Soil parameters were extracted from SoilGrid Raster

Dynamic Agroforestry Coffee Crop (DynaCof) Model

The model provide extensive detail about coffee agroforest system. This can be broadly categorised into coffee bean yield, net primary productivity (NPP), gross primary productivity, biomass distribution, mortality rate of plant each part and evapotranspiration.

Model Parameterisation

The model was originally developed for *Arabica* coffee; therefore, parameters distinguishing both species were adjusted to represent the *Robusta* coffee agroecosystem (Table 1). The model was trained using data from seven districts and its performance was validated in three additional districts. The Monthe Carlo analysis was applied during model calibration in the training districts to test the parameter ranges and identify the optimal configuration.

5. Statistical Indicators

Model performance was assessed by statistical indicators such as coefficient of determination (R^2), Index of Agreement (D-Index), and Normalized Root Mean Square Error (nRMSE). For deeper analysis of the model, a residual plot was created.

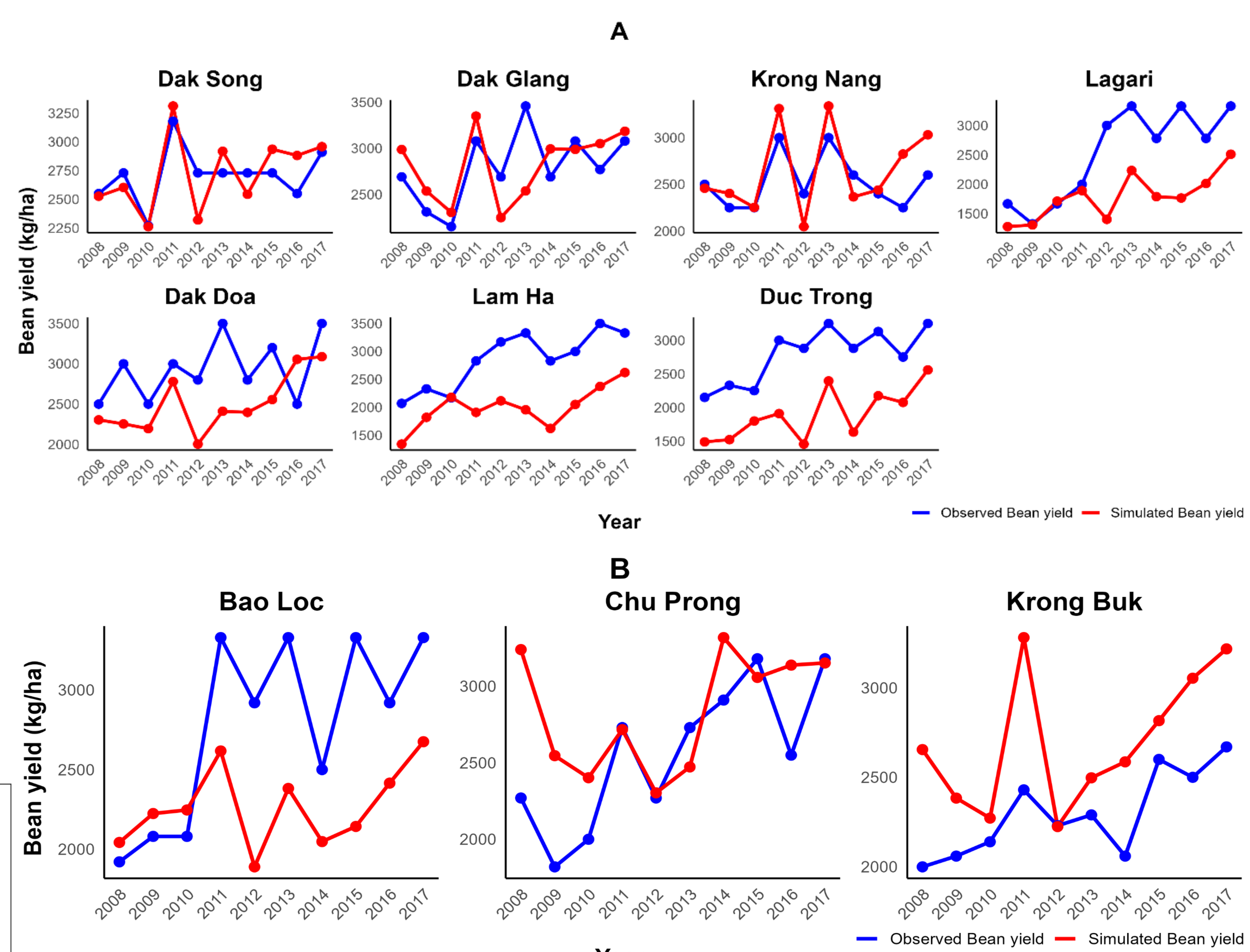

Figure 1. Temporal trend in bean yield for districts used in model training (A) and validation (B)

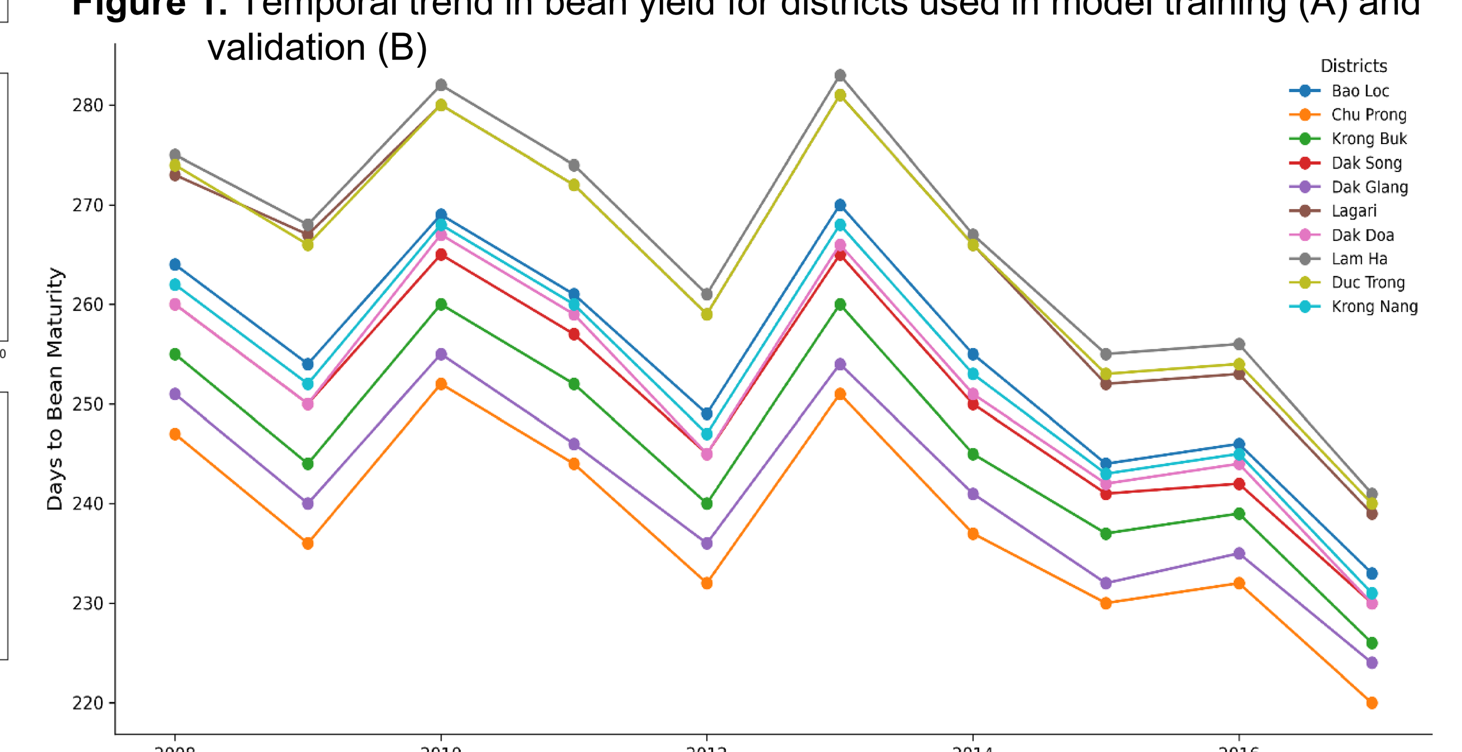

Figure 2. Days to bean maturity by coffee plant

CONCLUCION

- ❖ Improved DynACof model to successfully predict the Robusta bean yield
- ❖ Analysed the parameters' performance and identified the ones most affecting crop yield and growth simulation
- ❖ Improved DynACof model to successfully predict the Robusta bean yield

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