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Crop growth models for tropical perennials: current advances and remaining challenges

Rozendaal Danaë M.A.[1] (danae.rozendaal@wur.nl), Slingerland Maja[1], Zuidema Pieter A.[2], Giller Ken E.[1], Anten Niels P.R.[3]

[1] *Plant Production Systems Group, Wageningen University and Research, Wageningen, Netherlands*; [2] *Forest Ecology and Forest Management, Wageningen University and Research, Wageningen, Netherlands*; [3] *Centre for Crop Systems Analysis, Wageningen University and Research, Wageningen, Netherlands*

Introduction

Production of major global commodities like cacao, coffee, and palm oil largely depends on smallholder farmers that have little access to inputs. Yields lag far behind from what is theoretically possible, and climate change is expected to strongly influence future production. The perennial nature of these crops implies that initial decisions on cropping system design will determine crop yields over decades. Crop growth models for perennials are much-needed to design sustainable, climate-smart production systems, because long-term empirical data on the physiology, growth and yield of perennials are scarce. Compared to annual crops, model building for perennials faces specific challenges. Perennials develop over multiple years, thus effects of climate, and management practices like fertilizer application, can have long-lasting effects on growth and yield (van Vliet and Giller 2017; Woittiez et al. 2017). Effects of specific management practices, like pruning, have also to be taken into account.

We are developing and updating process-based models for cacao and oil palm to improve yield projections. We will discuss ongoing model development and general challenges associated with building crop models for perennials, and we will provide an outlook to future model development.

Materials and Methods

Physiological crop growth models for cacao (CASE2; Zuidema et al., 2005) and oil palm (PALMSIM; Hoffman et al., 2014) were constructed, and further development of these models is ongoing. In both models, crop growth is modelled as a function of solar radiation, and both potential and water-limited yields can be simulated. Soil nutrient availability is assumed to not limit growth. For cacao, the perennial growth form is incorporated based on a feedback mechanism between biomass investment and loss. Rules of biomass gain and loss are based on allometric relationships between total tree biomass and biomass investment in parts of the tree (leaves, stems and branches, roots and fruits; Zuidema et al., 2005). For oil palm, a realistic plant structure is maintained in the model by including root mortality as a function of root biomass and an age-specific maximum leaf (frond) biomass controlled by pruning (Hoffmann et al., 2014).

Results and Discussion

Model validation indicated that CASE2 and PALMSIM perform well, thus these models offer potential for estimating yield gaps over large geographic areas, projecting influences of climate change on yield, and tailoring cropping system design to current and future climatic conditions. We will show current advances on the incorporation of effects of increasing CO_2 on crop yield, which may buffer negative effects of increasing temperature on future yield (Verhage et al., 2017).

We will also show results of new model parameterization and validation. Remaining challenges are (1) the validation of long-term output of the models, because long-term, high quality yield data are scarce; (2) the incorporation of soil nutrient effects; (3) accounting for long-term, temporal variation in flowering and fruiting phenology; and (4) the incorporation of effects of pruning (for cacao) on crop growth and yield.

Conclusions

Physiological models for tropical perennials are essential tools to evaluate the effects of climate change and management on yields. Yet, further model development on global change responses (CO_2 fertilization, drought) and management practices (nutrient effects and pruning) are needed.

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Keywords: Physiological models, cacao, oil palm, climate change.

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