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

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Background

- Production of cacao and palm oil largely depends on smallholder farmers: yields lag far behind from what is theoretically possible, and climate change is expected to strongly influence future yields.
- Crop growth models are essential for designing sustainable, climate-smart production systems: long-term empirical data on physiology, growth, phenology (flowering and fruiting), and yield are scarce.
- We are further developing physiological models for cacao (CASE2; Zuidema et al. 2005) and oil palm (PALMSIM; Hoffmann et al. 2014; Hekman et al. 2018), and developing a functional-structural plant (FSP) model for cacao.
- In CASE2 and PALMSIM, crop growth is modelled as a function of solar radiation (potential yield) and soil water availability (water-limited yield), assuming no effects of soil nutrient limitation, pests, weeds and diseases.

Modelling perennials: challenges

- Effects of system design, climate, and management practices (e.g. fertilizer application; van Vliet and Giller 2017; Woittiez et al. 2017) can persist over multiple years.
- Specific management practices for perennials, like pruning alter tree architecture.
- Validating (and modelling) long-term, temporal variation in yield: scarce data for validation.
- Incorporation of soil nutrient effects.

Modelling cacao yield: current advances

- With CASE2, we are estimating yield gaps in Ghana, and possible shifts in the cacao growing area due to climate change, accounting for physiological responses to increased temperature and altered precipitation patterns.
- We are currently incorporating the interaction between temperature and CO_2 in CASE2. As such, we can assess effects of increasing CO_2 on cocoa yield, which may buffer negative effects of increasing temperature.
- In CASE2, shading is included through one, overall reduction in light availability. We are working on a FSP model (Figure 1) to assess effects of heterogeneous shading in agroforestry systems. With the FSP model, effects of pruning on architecture and canopy photosynthesis will also be explored.

Figure 1. Prototype of a FSP model for cacao to explore effects of shading and pruning (credit: Pedro Janssen).

Cacao pods

Oil palm plantation

Modelling oil palm yield: current advances

- A new version of PALMSIM (v2.0; Hekman et al. 2018), has been used to estimate yield gaps for Indonesia (Figure 2).
- PALMSIM v2.0 includes fruit bunch filling as sink, within-year fluctuation in assimilates, and effects of water stress on sex ratio, inflorescence abortion and bunch failure.
- The challenge to better simulate effects of drought remains: in West Africa, for example, seasonal yield fluctuations persist even with irrigation (Rhebergen et al. 2019), suggesting photoperiod control.

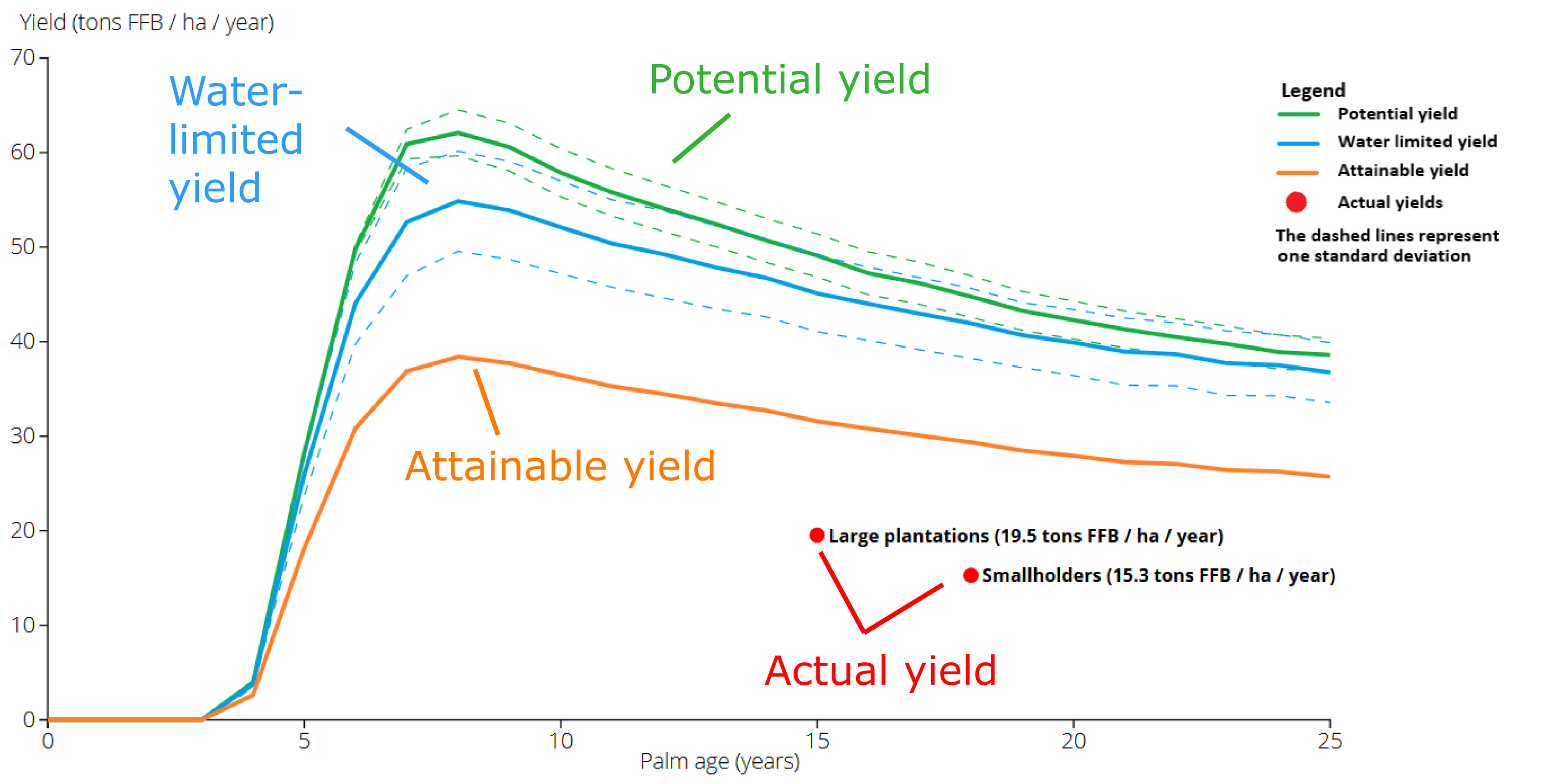

Figure 2. Yield gap analysis for Indonesia, based on PALMSIM (http://www.yieldgap.org/indonesia-oil-palm). GYGA project WUR, UNL, partners Indonesia

Conclusions

- CASE2 and PALMSIM offer potential for estimating yield gaps over large areas, projecting climate change influences on yield, and tailoring system design to current and future climatic conditions.
- FSP modelling is a promising tool for assessing effects of shade and pruning.
- Further model development on global change responses (effects CO_2 fertilization and drought) and management practices (soil nutrient effects and pruning) is much-needed.

References

- Hekman W. et al. (2018). Estimating yield gaps in oilpalm in Indonesia. Using PALMSIM to inform policy makers on scope for yield intensification. IOPC, 17-19 July, Medan, Indonesia
- Hoffmann MP et al. (2014). Simulating potential growth and yield of oil palm (*Elaeis guineensis*) with PALMSIM: Model description, evaluation and application. Agric Syst 131: 1-10.
- Rhebergen T et al. (2019). The influence of water and nutrient management on oil palm yield trends on a large-scale plantation in Ghana. Agric Water Manage 221:377-387.
- van Vliet JA, Giller KE (2017). Mineral nutrition of cocoa: a review. In Sparks DL, ed. Advances in Agronomy 141: 185-270.
- Woittiez et al. (2017). Yield gaps in oil palm: A quantitative review of contributing factors. Eur J Agron 83: 57-77.
- Zuidema PA et al. (2005). A physiological production model for cocoa (*Theobroma cacao*): model presentation, validation and application. Agric Syst 84: 195-225.

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