Modelling peanuts for nut-in-shell and fodder yield in the northern Australian tropics

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Abstract

Peanuts are a popular crop grown for their nutrient-rich nuts-in-shells. These crops also play a crucial role in enhancing the sustainability of farming systems. In addition to the nuts-in-shell, which the crop starts producing below-ground four to six weeks after sowing, peanuts make a substantial amount of above-ground biomass, mainly nitrogen-rich green foliage, stems, and branches. We hypothesized that some part of the above-ground biomass could be harvested or grazed without affecting the growth of the developing pods, making it valuable fodder for cattle or dry hay, especially in times of scarcity. In various tropical regions of northern Australia, experiments supported by the Cooperative Research Centre for Developing Northern Australia (CRCNA) have explored the dual potential of peanuts - for both nuts-in-shell production and grazing purposes. Leveraging the data from these experiments, we have refined and validated the APSIM model to simulate these dual-purpose capabilities of peanuts. This presentation aims to delve into this model's applications to explore the dual-purpose potential of peanuts in two environments.

Keywords

Dual-purpose peanuts, nut-in-shell, fodder, regrowth, *Arachis hypogaea* L., groundnut

Introduction

In Australia, peanuts are mainly grown for their edible kernels. The nitrogen-rich above-ground biomass is usually returned to the soil to maintain fertility. The peanut haulm (leaf and stem residue) is also used as animal feed during fodder scarcity (Özyiğit and Bilgen, 2013). Harvesting this biomass before the crops reach maturity would allow them to be used as animal forage while still enabling the crop to recover from the loss of green leaf area. Peanuts haulm, with crude protein levels ranging from 12 to 19 %, can support the healthy growth of ruminant animals such as sheep and cattle (Prine et al., 1981) while still producing valued nuts. Similar practices have been implemented in canola, and their potential has been assessed using APSIM (McCormick et al., 2015; McGrath and Friend, 2015; Watt et al., 2023). However, more information is needed before this practice can be recommended to peanut growers.

Apart from evaluating the potential of peanuts for dual purpose in field experiments, crop models could also be used for such evaluation. Crop models for assessing the potential of peanuts for dual purpose have not yet been developed. Unlike some other crops, peanuts require a certain amount of green leaf mass for easier harvesting of kernels. Therefore, maintaining a critical biomass level for recovery after cutting is important to maximize pod yield. Research in the USA suggested that peanut pod yield decreased by approximately 12% after a single forage harvest, and the decrease was even more significant with multiple harvests of in-season biomass (Sorensen et al., 2009). A preliminary experiment conducted in 2022-23 at Emerald showed an average 10% reduction in the pod yield of 13 cultivars due to cutting, which included both varieties released for commercial cultivation in Australia, including Holt, and new exotic lines (data not shown). However, the overall pod yield in this experiment was only around 1.4 t/ha, while the dry weight of biomass cut averaged 0.77 t/ha. Modelling peanuts for dual purposes could enable growers to determine when plants can tolerate the mechanical removal of a certain fraction of their growth without adversely affecting yield. With limited information on this aspect for dual-purpose peanuts in Australia, experiments were conducted in Emerald to determine the impact of foliage mass removed from the crop on peanut pod yield. The objective of this study was to develop a model to serve as a decision-support tool leveraging the data from these experiments.

Methods

Field trial

The trial to assess the potential of peanuts as a dual-purpose crop was established on 5 December 2023 near Emerald in central Queensland, Australia. The field's soil was a sandy loam with an assumed plant available water holding capacity of 160 mm in the 0-150 mm soil layer based on dry matter production achieved in the experiment with 13 peanut cultivars conducted in the 2022/23 season at the same site. The 2023-24 trial was planted to cultivar Holt at 0.90 m row spacing to attain approximately 15 plants/m^2. The crop in the field was irrigated whenever there was at least 15 mm depletion of soil water from the profile, and the amount of water applied generally represented approximately 5.4 megalitres, which is typical for crops grown in the Emerald region.

At 72 days after sowing, when the crop was approximately 40 cm in height, and the canopy cover was > 90 % (as measured by Canopeo software), it was cut approximately at 10 cm above the ground to remove peanut biomass for forage (see Figure 1). The cut and uncut (leftover) biomass was then estimated in a 1 m^2 quadrant. The biomass was weighed after drying at 65 °C for up to 4 days until constant weight was achieved.

Modelling

The APSIM Classic peanut model (version 7.10) was modified to simulate how cutting impacted leaf area, number, biomass, and pod yield for Emerald in central Queensland. The model was programmed with rules that allowed the crop to be harvested at specific dates and different heights to mimic recovery from cutting. The simulated data were then compared with the observed values of the cutting height of 10 cm and uncut height of 40 cm (control).

After a preliminary evaluation of the model, long-term simulations (1957 to 2024) were conducted for two locations: Emerald, which is in the central highland region of Queensland, and Mossman, a coastal cane-growing region located 76 km north of Cairns. Diversification of the cropping system with crops, including peanuts, has become necessary in Mossman due to a decline in the sugarcane industry. The climatic data for these locations was obtained from the Silo Patched Point Dataset (https://www.longpaddock.qld.gov.au/silo/). The plant available water holding capacity of the soil in Emerald (a Red Dermosol) was 160 mm, and in Mossman (a Yellow Dermosol) it was 135 mm.

Results and Discussion

The simulated and observed values of key traits, including plant height, leaf area index, biomass, and per cent canopy cover at cutting time (72 days after sowing), were similar (Table 1). In the experiment conducted in 2023-24, Emerald, the dry weight of biomass cut averaged 2.5 t/ha, whereas the uncut biomass was 4.22 t/ha. The total biomass at the cutting stage averaged 6.7 t/ha. The only large discrepancy between simulated and observed data was an overestimation of the amount of biomass removed in cutting. A substantial amount of biomass in a Runner peanut like Holt could be near the ground and not harvested as it lies within 10 cm of plant height. It will also be unrecoverable when bailing is done by machine. This discrepancy, which could be an artefact of the cutting method, could be corrected by inserting a function to correct this discrepancy. As further data were compromised due to cockatoos' damage, evaluating the model performance after this stage has not been possible.

Table 1: Observed and simulated values of crop traits at 72 days after sowing in Emerald experiment conducted in 2023-24.

	Canopy Height (cm)			Canopy	TDM (t/ha)		
	at cut	after-cut	LAI	cover (%)	at cut	removed	% removed
Observed	38.4	9.6	4.7	91.7	6.7	2.5	40
Simulated	44.6	10.0	4.6	87.4	6.7	4.3	60

In simulations for Emerald's 2023-24 season, we noted that cutting peanut plants at a certain height led to a decrease in plant height, leaf area index, and biomass (Figure 2a, b & c). Cutting caused a 17% reduction in pod yield (simulated) (Fig. 1d) due to removing 3.77 t/ha of biomass 72 days after sowing the crop. This reduction was consistent with the findings of Sorensen et al. (2009) in the USA and near to the reduction exhibited in the preliminary experiment (Emerald 2022-23). Removing the peanut canopy for biomass presented practical challenges in addition to the loss in pod yield. Birds, especially cockatoos, were attracted to the high nutritional value of the developing peanuts and found it easier to access them after the canopy was removed. The current APSIM model does not consider yield losses due to birds, but new laser devices designed to control bird damage significantly mitigate this risk.

Figure 1. Bailing of peanut for hay in February 2024 in the experiment for evaluating potential of peanut for dual purpose.

Long-term simulations for the Emerald area showed results consistent with the 2023-24 simulations, indicating a slightly lower (11%) pod-yield reduction when harvested at 10 cm height at 72 days after sowing (Figure 3). The maturity biomass in both cut and uncut treatments generally increased with time almost at the same rate (Figure 3a). In comparison to Emerald, the Mossman site exhibited higher pod yield and biomass, despite a similar reduction due to foliage harvest. The crop must generate significant biomass to address climate change by sequestering more carbon in the soil, reducing soil degradation, and meeting foraging needs. Therefore, the dual-purpose peanuts may be more successful in coastal areas of north Queensland, where farmers seek alternative crops that require less fertilizer to decrease runoff water loss. In contrast, in inland peanut-growing areas like Emerald, limited rainfall and unfavourable temperatures could restrict the effectiveness of this practice due to their potential impact on crop recovery from biomass removal. More work may be required to identify agronomic practices that will enable the potential of dual-purpose peanuts to be realized, even in inland areas.

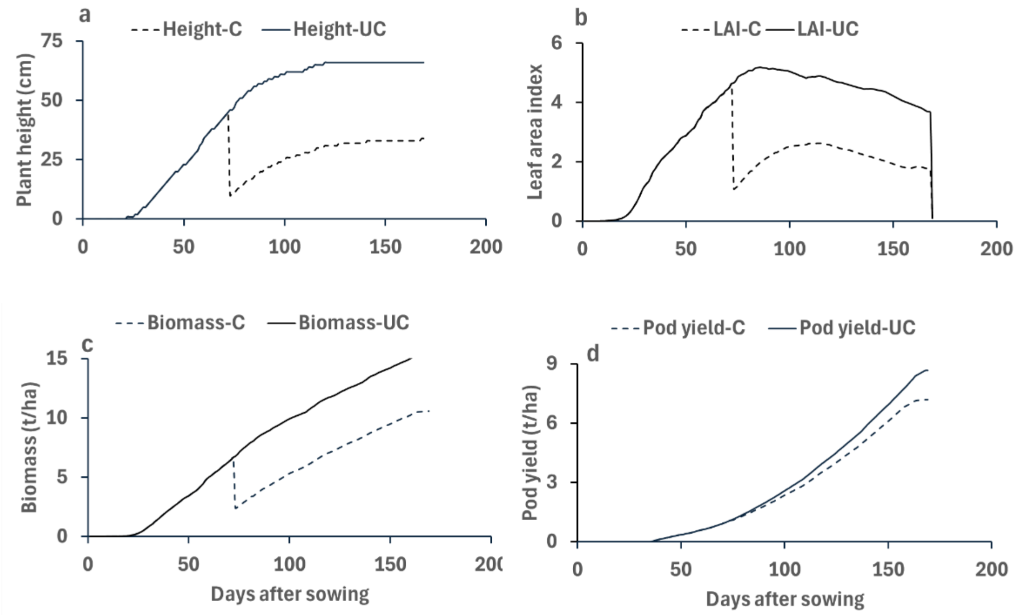

Figure 2. Plant height (a), leaf area index (b), biomass (c), and pod yield (d) trends of the full-season peanut cultivar Holt were simulated by APSIM in cut (C) and uncut (UC) treatments. The cutting treatment was applied 72 days after sowing as part of an experiment conducted in Emerald in 2023-24. The values for plant height, LAI, and biomass generally matched the observed values on the day of cutting.

Conclusions

The dual-purpose peanut model we have developed can allow for the assessment of the impact of the removal of biomass on pod yield well and could be used to assess the potential of such systems in diverse environments when we applied the model to compare the potential in central Queensland and the northern coastal environment. We found that the potential of dual-purpose peanuts was better in the coastal region where biomass production was higher and pod yield was less influenced by cutting.

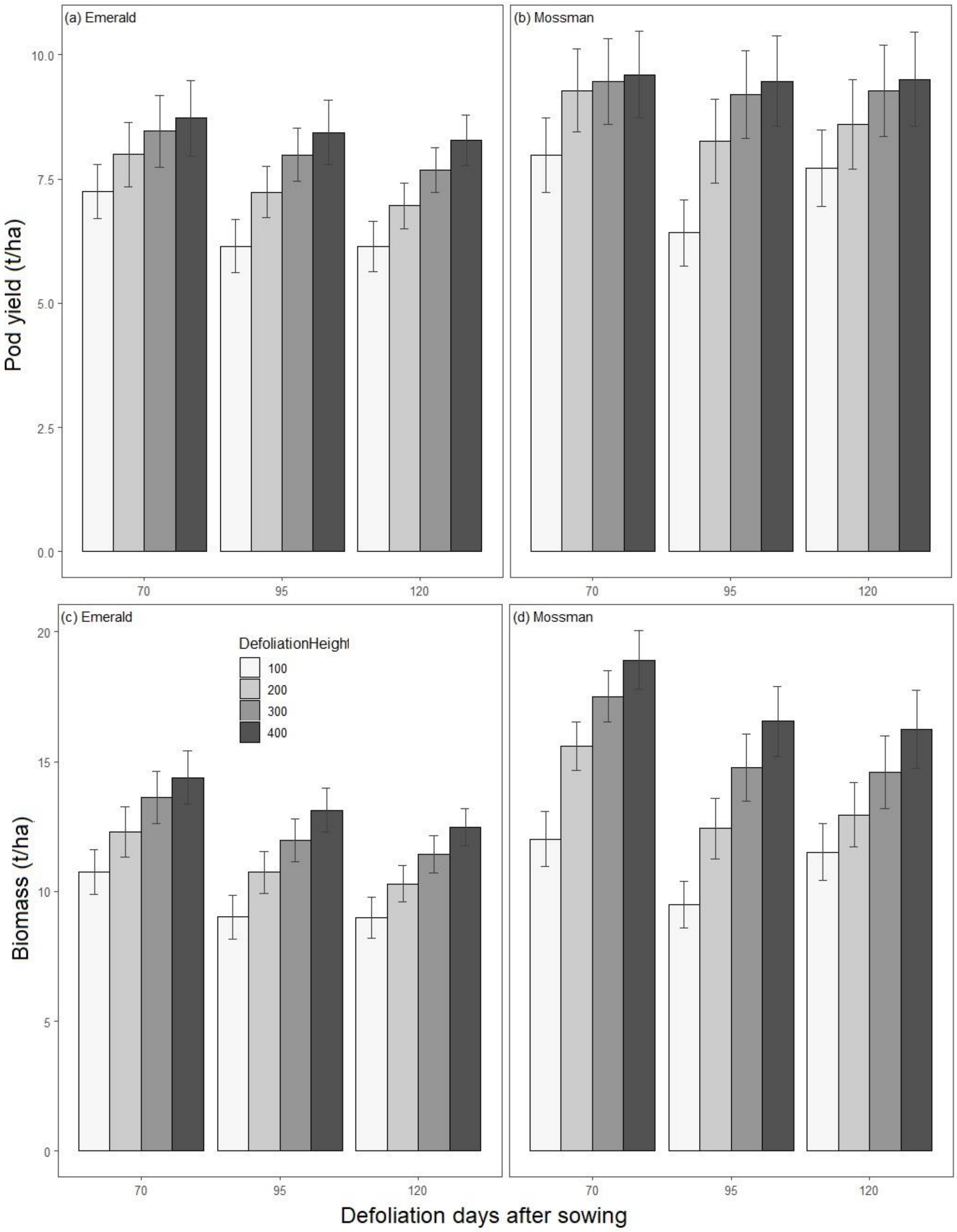

Figure 3. The simulated impact of cutting height (mm) at different days after sowing on peanut pod yield (a,b) and biomass (c,d) for a full season peanut grown at Emerald (a,c) and Mossman (b,d) from 1957 to 2024. Deficit irrigation of 15 mm was applied. Error bars are standard deviation indicating seasonal variability in pod yield and biomass.

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