A software for the simulation of rainfall distribution on 3D plant architecture: PyDROP

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Introduction

Rainfall interception is highly dependent on plant architecture and affects key plant-environment relationships like plant water budget, soil hydrology and erosion, chemical leaching or disease propagation and development. Banana plantations in the tropics combines plant architectures with important funnelling properties, frequently high rainfall rates and sometimes important agrochemical use. In order to assess erosion and pollution hazards in banana plantations we developed a software simulating rainfall interception by 3D plant architecture.

The DROP model was created to simulate water flows on the plant and predict location of preferential pathways using geometrical and topological information obtained from 3-D digitising. (Bassette, 2005). We presented here new features, assembled in the PyDROP software, that were developed to build virtual plots combining plants of various ages and shapes and simulate rainfall interception on them. For this purpose we (i) account for elementary leaf surfaces water budget including primary and secondary rainfall interception, splashing and storage (ii) developed new algorithms for the triangulation of digitised data of complex leaf shapes (iii) developed a user-friendly computer interface for virtual banana plot construction, output visualisation, and possible use in a software platform (OpenAlea).

DROP model principles

The DROP (Distribution of Rainfall On Plant) model simulates water flows on plants. The DROP-TRI module provides the 3-D representation of the plant as a set of triangles from digitised data and the module DROP-INT simulates rainfall interception and water transfers on these triangles according to plant topology. (Bussière et al., 2002; Bassette and Bussière, 2005).

Rainfall interception simulation

Water retention and splashing from primary rainfall (rainfall) and secondary rainfall (drips from leaves above) were estimated in the DROP model according to surface position and inclination by empirical relationships (Bassette, 2005; Bassette and Bussiere, 2007).

Field data acquisition and triangulation

Virtual mock-up of banana plants up to 6m tall were built using plant coordinates collected with an electromagnetic digitiser (Fastrack Pholemus). For each leaf, points on each edge of the limb and on the midrib were recorded every 1 to 10 cm according to the geometry. Leaves of the top of the canopy, torn by wind, exhibited complicated shapes that cannot be classically simulated by Delaunay triangulation (Loch, 2004). The triangulation of a 3D polygon with potential overlapping is a NP-complete problem (Barequet et al., 1996) and we combined heuristic methods and adaptations of algorithms from Mündermann and Held to solve it (Mündermann et al., 2003; Held, 2001) Digitised points of leaves represented 3D polygons that were projected on planes maximising their surface and then were divided into smaller polygons according to the shortest diagonal between angles from the edge of the limb and the midrib. This process was applied recursively until each polygon was divided into triangles. When it fails, Held algorithm was applied (Fig. 1) (Dufour-Kowalski and Bussière, 2006). When compared to LICOR LI3100 planimeter measurements errors in total leaf area estimates did not exceeded 10% (Bassette and

Bussière 2005). Fifty plants were thus available in the database.

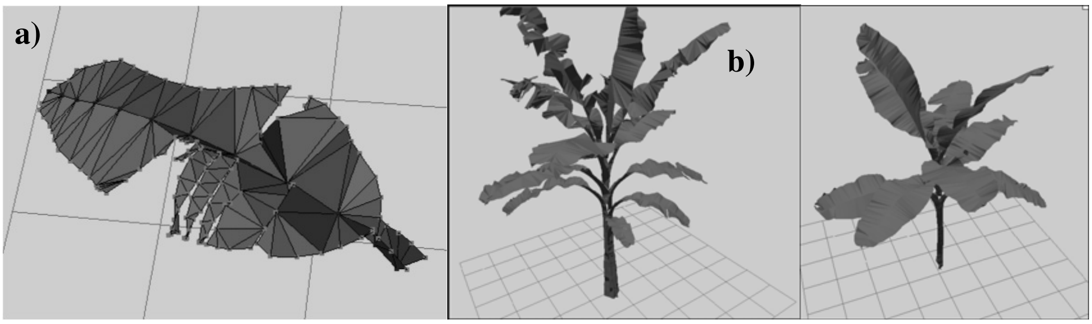

Fig. 1: Visualisation of mock-ups obtained from digitalised and triangulated plants. **a)** Torn leaf triangulation obtained from digitised points on the lamina edges and on the midrib. **b)** Plants of different ages and growth conditions.

PyDROP software:

Previous DROP modules and new features were integrated in a modular and multi-platform software written in Python language. This high level, interpreted and modular language allows either automation scripts for large data set treatments, or easy model improvements and future developments. The modular structure allow the use of modules independently and the further integration in the OpenAlea visual programming software (Pradal et al., 2004).

The main PyDROP modules are:

- The **plant manager** that must be used to build plots with banana plants from the database or imported digitised data files. (Fig. 2).
- The **mesh** module that creates sets of triangles from digitised data as presented above.
- The **rain interception** module that computes splash and storage of rain drops on elementary surfaces and then the transmission of water between surfaces or drippings.
- The **viewer** implemented with PyQt4 and OpenGL libraries that displays local or global plant architecture, visual simulation outputs like map of water flows at the soil surface (Fig. 2).

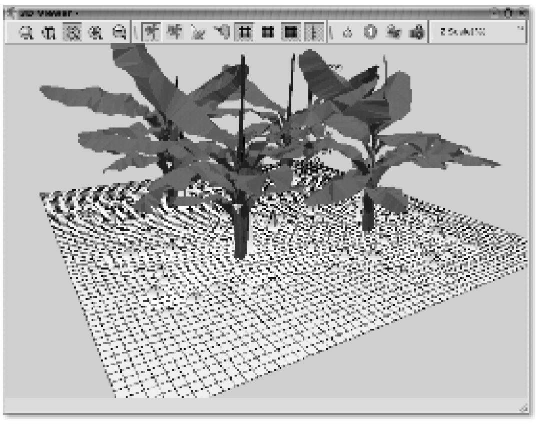

Fig. 2: Screen shot of the PyDROP viewer representing the map of transmitted rainfall below four young banana plants

Use of PyDROP for rainfall distribution assessment

PyDROP was used to compare two patterns of banana plantation for water flow management (Fig. 3). In the square plantation, the rows are evenly separated by a 2.35 m space while in the double row plantation rows are alternatively separated by 1.5 or 3 m. The amount of water stored and splashed on the four same plants were less for square plantation than for double row plantation except for the stemflow of plant 2 and 4. The stemflow of the plant 2 was greatly reduced by double row plantations because of the increased plant overlapping.

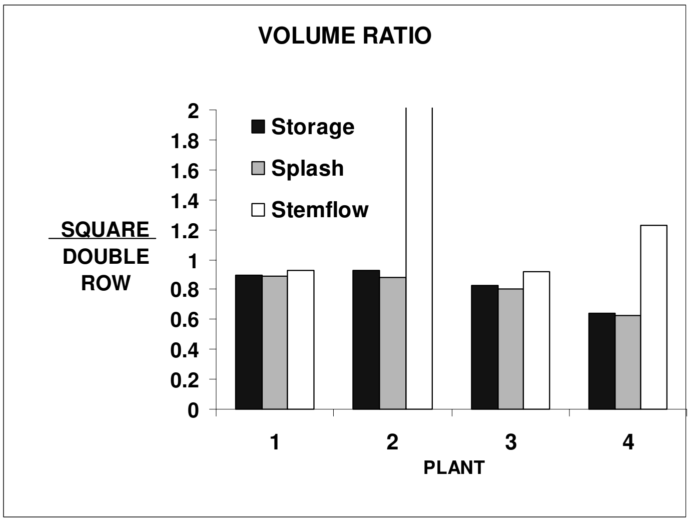

Fig. 3: Comparison of water amount in storage, splash and stemflow for four plants on a square or double rows patterns. Bar graphs represent for each plant, the volume ratio of the two patterns

Conclusion

We developed a new software for the simulation of rainfall interception and redistribution on plants. This software included a database of varied banana plants that can be used to design plant patterns for simulations. New triangulation algorithms were developed for the simulation of complicated banana leaf shapes. Simulation of rainfall interception account for water retention, splashing and funnelling on plant surfaces Outputs of the model were design for water flux assessment on and below the plants. The modular design of the PyDROP model facilitate further use of other geometrical data (i.e for other plant types), or the coupling with other models like radiative transfer models. The future implementation of new processes like energy budget will allow further estimate of surfaces wetness duration and hence the use of the PyDROP model for fungal disease investigation.

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