Plant growth modelling

Keywords : Plant growth; Modelling; System identification.

Denis Dochain, Heather MacLean

Abstract* – *This research activity deals with the development and identification of a simple mass balance model for plant growth. Photosynthesis and respiration have been selected as key reactions for biomass production. The model has been developed using a mass balance approach.

This reasearch activity has been initiated under the auspices of the European Space Agency (ESA), and more in the framework of the MELISSA project. The MELiSSA (Micro-Ecological Life Support System Alternative) project aims to develop technology for a future regenerative life support system for long term manned space missions. Developed by the European Space Agency, the concept is to use microorganisms and plants to regenerate the atmosphere, recycle water, and to produce food for the crew on such missions. An important part of the MELiSSA loop is the growth of higher plants in a controlled greenhouse environment for the production of food and oxygen from 'waste' carbon dioxide. A model of plant growth is required for the prediction and eventual control of this compartment. The model must be applicable at normal operating conditions, as well as during failure and stress conditions. The main control objective will be to provide a certain desired 'flow' of biomass from the plant chamber as food for the crew. Both quantity and nutritional requirements will need to be maintained.

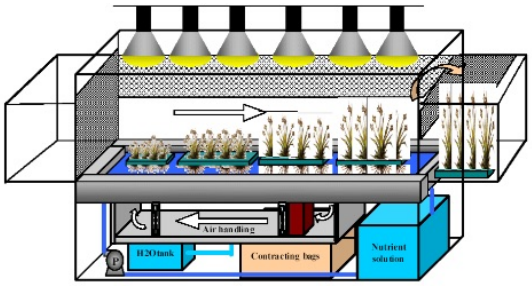

Figure 1: Schematic view of the greenhouse.

Two plants, lettuce and red beet, have been studied in the context of the MELISSA project. Further developments have been performed with another plant, Arabidopsis, from experiments designed and implemented at the LEPSE (Laboratoire d'Ecophysiologie des Plantes sous Stress Environnementaux) of the INRA in Montpellier.

Plants are complicated systems. Their growth and development involve a large number of interconnected processes and reactions. Plant models cannot incorporate all of these processes, and therefore those that are most important need to be selected. To simplify the selection process, only total biomass production was considered, and therefore biomass partitioning was not included at this stage. In the first model selection, only photosynthesis (3), photorespiration (4), and mitochondrial (or dark) respiration (5) were considered. These reactions were selected because they are the main reactions influencing the production of biomass, as well as the exchange of carbon dioxide and oxygen between the plant and the atmosphere.

$$CO_2 + H_2O \xrightarrow{Light} Biomass + O_2 \quad (1)$$

$$Biomass + O_2 \xrightarrow{Light} CO_2 + H_2O \quad (2)$$

$$Biomass + O_2 \longrightarrow CO_2 + H_2O \quad (3)$$

The model has been further developed by considering development stages, in order to account for the change in metabolism. It is indeed known that biomass partitioning (the allocation of new assimilated carbon to the growth of different organs - leaves, roots, fruits, etc.) changes during development, and that these changes in partitioning could be linked to changes in metabolism that influence the flux of oxygen and carbon dioxide. The incorporation of development stages has been done by considering a transition test based on the photosynthetic quotient, which is the ratio of oxygen produced by the plants to the CO_2 consumed.

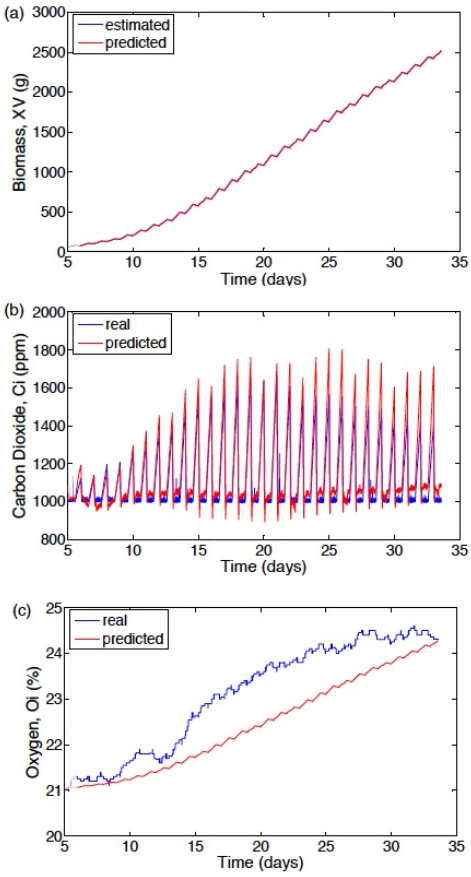

Figure 2: Model validation for red beet.

References

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