

Simulations of an impulsive model for the growth of fruit trees

Theme 08 - Introduction to Systems Biology
Reproduce research



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Abstract

Droughts have affected the agriculture in the mediterranean in an increasingly severe matter. The decrease in rainfall and the effects of global warming have taken their toll on many orchards, especially fruit producing ones. Since the water supply of these orchards is always artificial because of the aforementioned factors, dwindling water capacities in reservoirs is a serious issue. This study aims to provide an insight into the effects of different irrigation patterns on the growth of these fruit trees. Because without a sustainable plan for irrigation, whole populations of fruit trees might perish under a critical water deficit.

Summary

List of Abbreviations

ODE Ordinary Differential Equation

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1 Introduction

1.1 Purpose

The effects of climate change are an existential threat to planet earth. This paper's purpose is to reproduce and expand on the research done by E Duque-Marín to get a further understanding of the dynamics and different scenarios of fruit tree growth, and by extension shed light on a part of this humongous problem that is already cropping up around the world.

1.2 Theory

For use in the simulations, two differential equations were obtained from *E Duque-Marín et al 2022 J. Phys.: Conf. Ser. 2153 012018*. Their accompanying parameters are listed below.

Parameter	Meaning
q	Accumulated energy constant
r	Fruit trees intrinsic growth rate
N	Fruit carrying capacity
I	Irrigation water amount
β	Evapotranspiration rate
γ	Photosynthetic contribution rate
ω	Mortality rate of fruit trees

Equations :

$$\begin{aligned} W'(t) &= -\beta q W(t) - r C(t) \left(1 - \frac{C(t)}{N}\right) W(t) \\ C'(t) &= r C(t) \left(1 - \frac{C(t)}{N}\right) W(t) + \frac{\gamma q C(t) W(t)}{(C+1)(W+1)} - \omega C(t) \quad t \neq nT \\ \Delta W(nT) &= I \\ \Delta C(nT) &= 0 \quad t = nT \end{aligned}$$

These equations come forth from a plethora of different papers, all of these are listed in *E Duque-Marín et al 2021 J. Phys.: Conf. Ser. 2046 012017*, the paper which proves these equations.

2 Materials and Methods

Since no datasets were used in the production of the results, the simulation data had to be generated. This data was plotted using R graphics.

2.1 Materials

The simulation data was obtained using the ODE (ordinary differential equation) function of deSolve. This function takes differential equations and parameters and calculates the output of these functions. Aforementioned equations and parameters can be found in the theory section. Other packages like ggplot2, ggpubr, formatR and scales were used in data visualisation.

Software	Package	Version
R		4.0.4
	deSolve	1.32
	formatR	1.11.1
	ggplot2	3.3.5
	ggpubr	0.4.0
	scales	1.1.1

The simulation data consists of an index, the *time*, water level in the soil (*W*) and biomass (*C*).

	<i>time</i>	<i>W</i>	<i>C</i>
1	0.00000	0.600000	1.00000
2	1.00000	0.556209	1.02602
3	2.00000	0.514991	1.05076
4	3.00000	0.476281	1.07421
5	4.00000	0.440001	1.09637

2.2 Methods

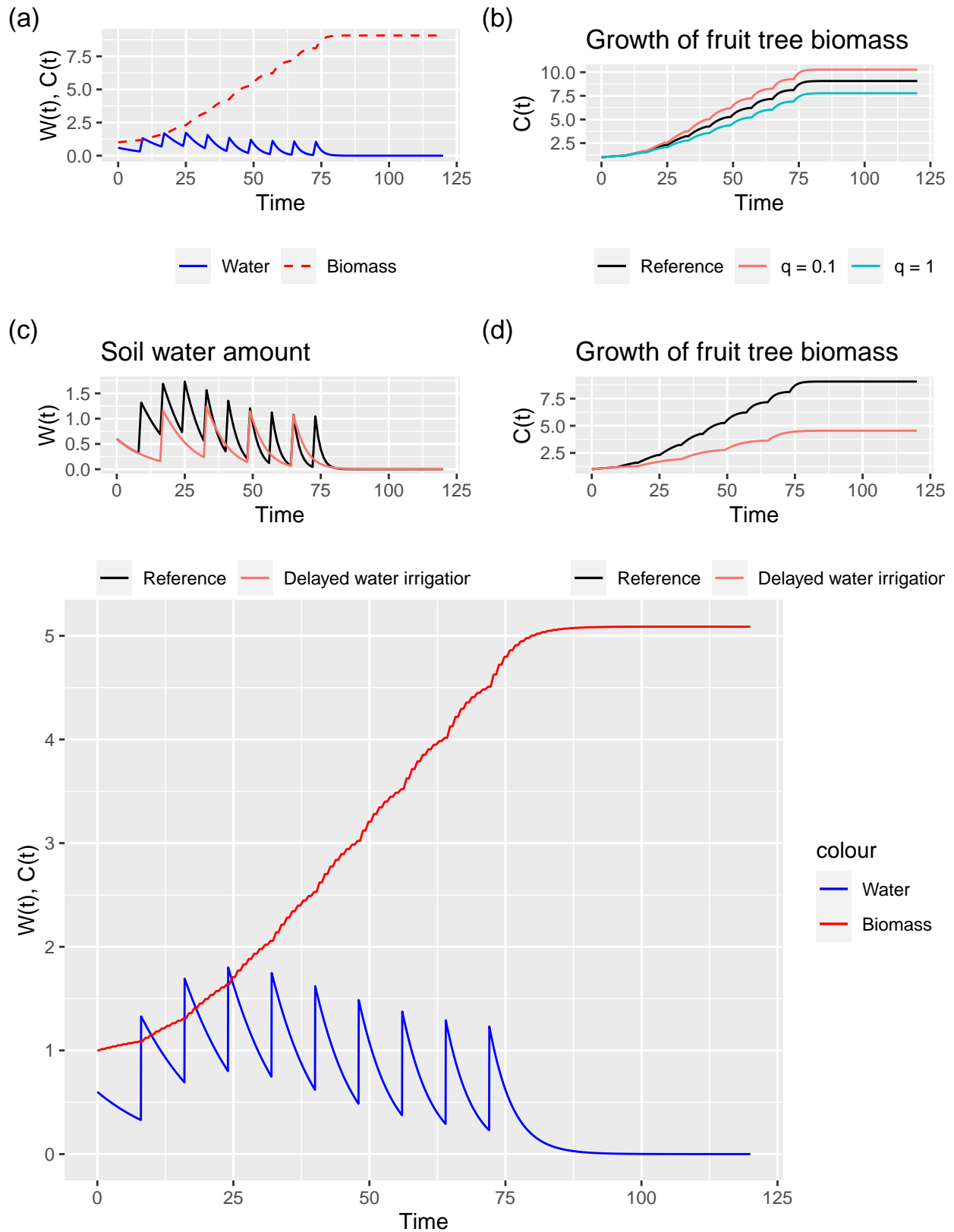
The differential equations were translated into a mathematical model that deSolve could understand. The last two equations also needed to be incorporated, this was done through if/else statements. After which several tests were run to ensure parity with the described model in the paper. File: results1.

After this, the model was updated to use 1h steps instead of 1 day. This led to the model being adapted to incorporate different growth rates for day and night, for even more precise data. File: results2.

Another few models were made to compare different irrigation intervals, as well as a model for watering the soil as soon as almost all water was drained from it. Files: results3 & results4.

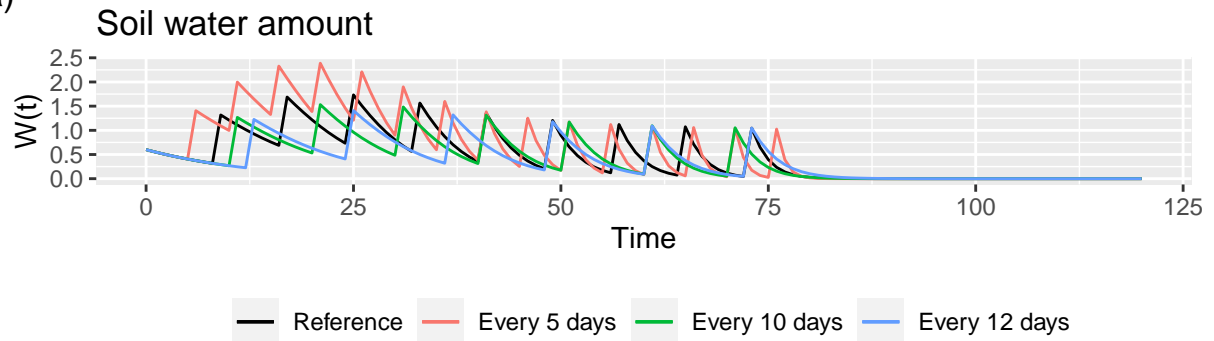
3 Results

Plots of the paper

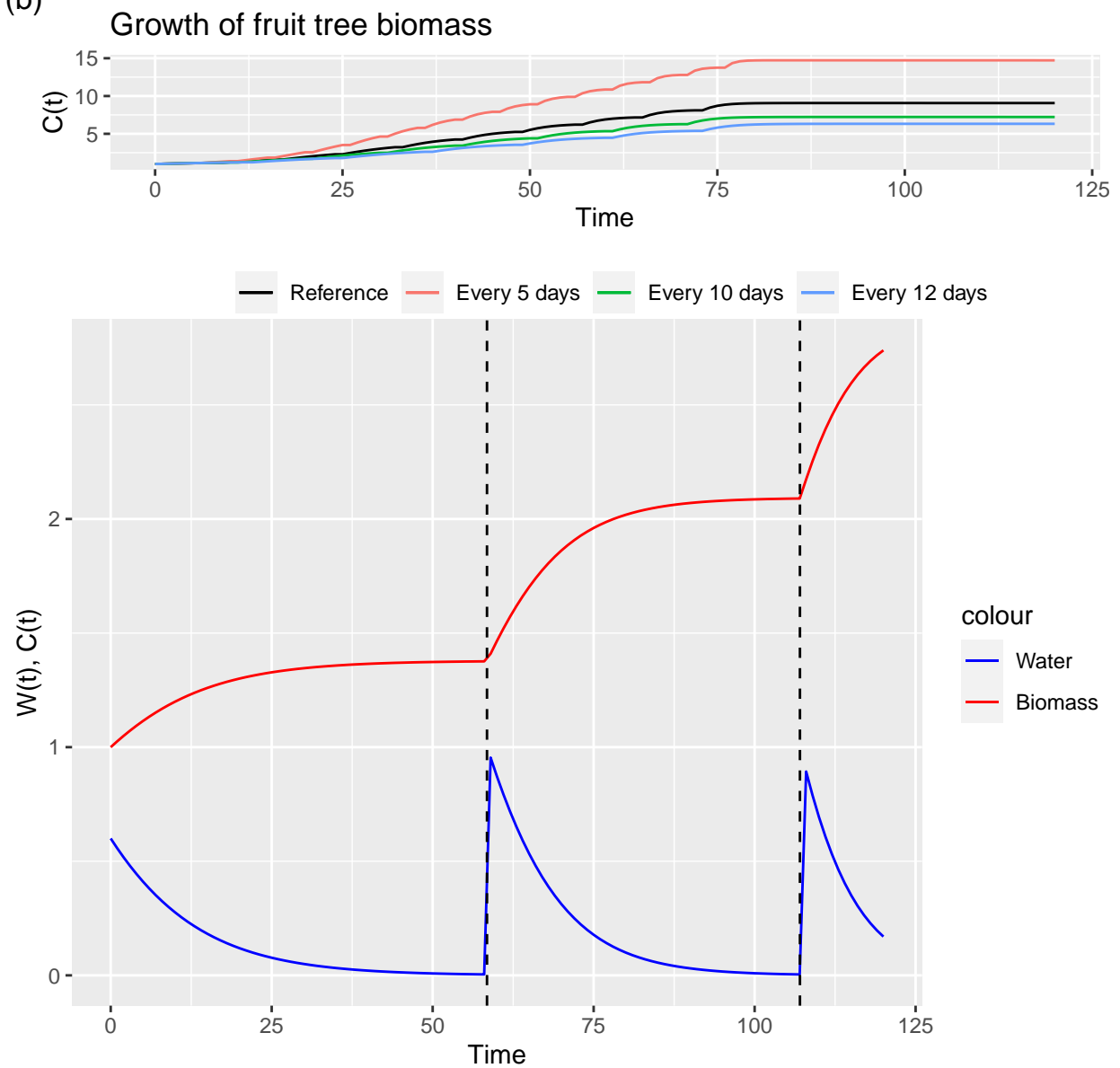


Water irrigation on different days

(a)



(b)



4 Conclusion

5 Discussion

6 References

7 Appendix