VII International Conference on Mathematics and its Applications in Science and Engineering (ICMASE 2026)

ICMASE 2026

A DETERMINISTIC MODEL OF STOMATAL CONDUCTANCE IN C3 PLANTS EXPLICITLY INCORPORATING LEAF TEMPERATURE

Viviana NIÑO-CELIS[1,*], Alejandro ROJAS-PALMA[3], Sergio ESPINOZA-MEZA[2], Leidy LARA-DÍAZ[3]

[1]*Doctorado en Modelamiento Matemático Aplicado, Facultad de Ciencias Básicas, Universidad Católica del Maule, 3466706 Talca, Chile*

[2]*Departamento de Ciencias Forestales, Facultad de Ciencias Agrarias y Forestales, Universidad Católica del Maule, Talca, Chile*

[3]*Departamento de Matemática, Física y Estadística, Facultad de Ciencias, Universidad Católica del Maule, Talca, Chile*

ABSTRACT

Extreme climatic events, such as heat waves and prolonged droughts, have intensified with climate change, directly affecting metabolic processes of C3 plants, such as photosynthesis and transpiration. These processes are associated with the functioning of stomata, microscopic pores located on the leaf surface that control CO_2 uptake and water vapor loss, processes quantified through stomatal conductance (g_s) [3, 4]. Under these conditions, the leaf-to-air vapor pressure deficit (VPD_l) and leaf water balance are directly modified [1, 2]. In this context, leaf temperature (T_l), which results from the continuous exchange of energy between the plant and its environment, represents the thermal state of the plant and constitutes a relevant variable for describing the plant response to environmental stress. In addition, T_l directly contributes to the estimation of VPD_l, since this deficit depends on the difference between the saturation vapor pressure at leaf temperature and the actual vapor pressure of the air [1].

Despite the importance of stomata in leaf thermoregulation, the specific stomatal responses to temperature and their influence on the dynamics of g_s remain a matter of debate [5]. Several studies have reported contrasting behaviors: while some indicate an increase in g_s with rising temperature, even under constant VPD_l [1], others highlight a decoupling between photosynthesis and stomatal conductance g_s under heat and drought conditions [5]. This variability reflects the complexity of the phenomenon and explains why the relationship between T_l, VPD_l, and g_s is still not fully understood.

Therefore, it is important to develop quantitative models that explicitly integrate T_l into the dynamics of g_s, considering the thermal and physiological mechanisms that can improve the prediction of stomatal behavior under global warming scenarios [6, 7, 8]. In this work, a dynamic model of g_s is formulated and analyzed for C3 plants, explicitly incorporating T_l and VPD_l. The model is formulated through a first-order ordinary differential equation for $g_s(t)$, considering different time constants for stomatal opening and closing processes. The target function is constructed from factors associated with photosynthetic photon flux density (Q), T_l, and VPD_l, in order to represent equilibrium conductance under environmental conditions. The analysis focuses on qualitative properties of the model, including existence and uniqueness of solutions. This formulation provides a mathematical basis for studying the transient response of g_s to environmental changes.

***K*eywords** Stomatal conductance · Dynamical systems · Ordinary differential equations · Asymptotic stability · Leaf temperature

[*]*Corresponding author's e-mail: vnino@ucm.cl*

References

[1] Urban, J., Ingwers, M., McGuire, M. A., & Teskey, R. O. (2017a). Stomatal conductance increases with rising temperature. *Plant Signaling & Behavior*, **12**(8), e1356534. Taylor & Francis. https://doi.org/10.1080/15592324.2017.1356534

[2] Huang, G., Yang, Y., Zhu, L., Peng, S., & Li, Y. (2021). Temperature responses of photosynthesis and stomatal conductance in rice and wheat plants. *Agricultural and Forest Meteorology*, **300**, 108322. Elsevier. https://doi.org/10.1016/j.agrformet.2020.108322

[3] Buckley, T. N. (2019). How do stomata respond to water status? *New Phytologist*, **224**(1), 21–36. Wiley Online Library. https://doi.org/10.1111/nph.15914

[4] Liu, K., Wang, Y., Magney, T. S., & Frankenberg, C. (2024). Non-steady-state stomatal conductance modeling and its implications: from leaf to ecosystem. *Biogeosciences*, **21**(6), 1501–1516. Copernicus Publications. https://doi.org/10.5194/bg-21-1501-2024

[5] Chen, Y., Liang, K., Cui, B., Hou, J., Rosenqvist, E., Fang, L., & Liu, F. (2025). Incorporating the temperature responses of stomatal and non-stomatal limitations to photosynthesis improves the predictability of the unified stomatal optimization model for wheat under heat stress. *Agricultural and Forest Meteorology*, **362**, 110381. Elsevier. https://doi.org/10.1016/j.agrformet.2024.110381

[6] Damour, G., Simonneau, T., Cochard, H., & Urban, L. (2010). An overview of models of stomatal conductance at the leaf level. *Plant, Cell & Environment*, **33**(9), 1419–1438. Wiley Online Library. https://doi.org/10.1111/j.1365-3040.2010.02181.x

[7] Buckley, T. N. (2017). Modeling stomatal conductance. *Plant Physiology*, **174**(2), 572–582. American Society of Plant Biologists. https://doi.org/10.1104/pp.16.01772

[8] Martínez-Jeraldo, N., Rojas-Palma, A., Carrasco-Benavides, M., & Osores, V. (2026). A modeling approach to stomatal conductance under different vapor pressure conditions. *Bulletin of Mathematical Biology*, **88**(7), 116. Springer. https://doi.org/10.1007/s11538-026-01676-6

[9] Vialet-Chabrand, S., Dreyer, E., & Brendel, O. (2013). Performance of a new dynamic model for predicting diurnal time courses of stomatal conductance at the leaf level. *Plant, Cell & Environment*, **36**(8), 1529–1546. Wiley. https://doi.org/10.1111/pce.12086

[10] Noe, S. M., & Giersch, C. (2004). A simple dynamic model of photosynthesis in oak leaves: coupling leaf conductance and photosynthetic carbon fixation by a variable intracellular CO_2 pool. *Functional Plant Biology*, **31**(12), 1195–1204. CSIRO Publishing. https://doi.org/10.1071/FP03251