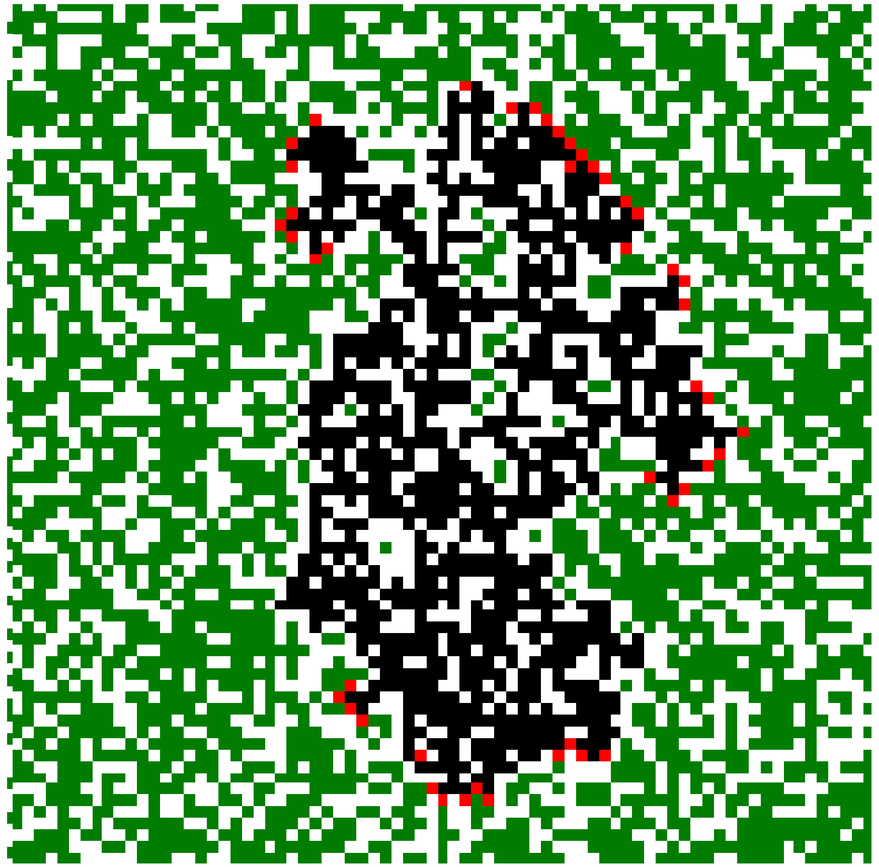
HOT TO G🔥

FOREST FIRE PERCOLATION MODELING

Intro | The Model | Results

MIKKO BRANDON, VICTORIA PETERSON, YOAD VAN PRAAG, RINSKE OSKAMP

Introduction



Research Questions

1	Do **forest fires** exhibit characteristics of **criticality**?
2	How does introducing **wind** into the system affect the critical density and does it still exhibit criticality?
3	How do **environmental influences** affect the critical density and does it still exhibit criticality?
4	How does a combination of a variety of **burnable vegetation types** and environmental influences affect the critical density and does it still exhibit criticality?

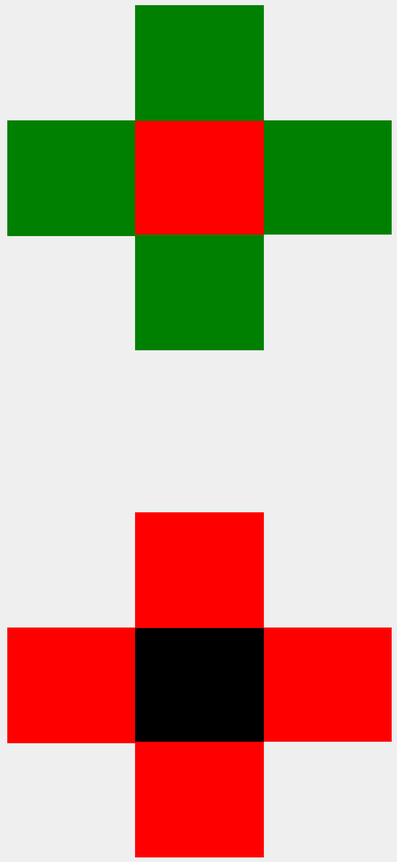
Model

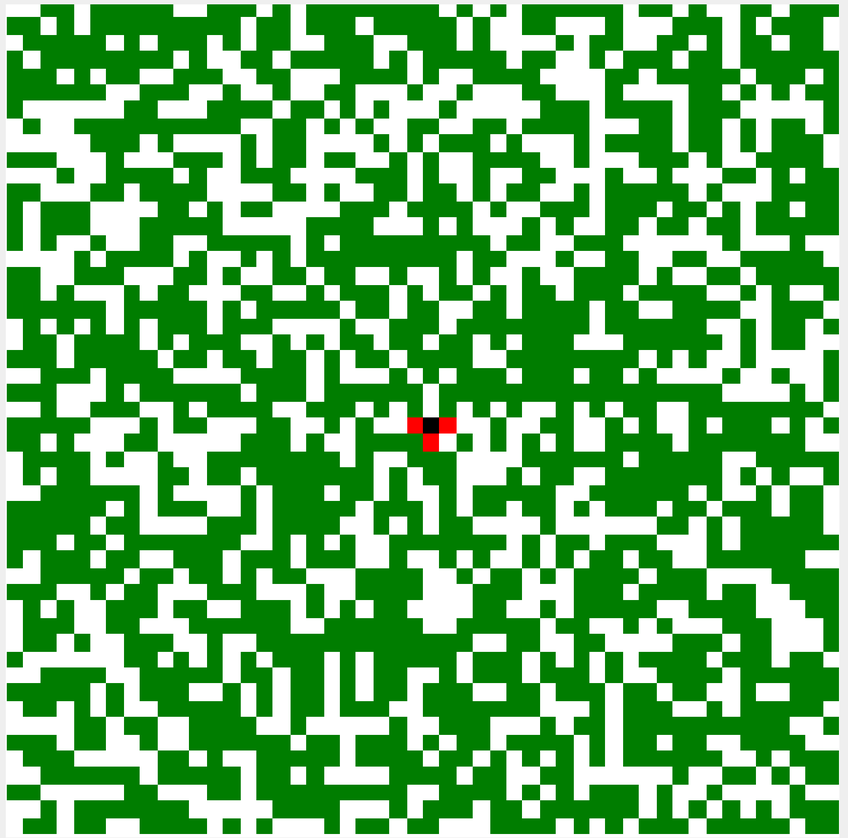
Modeling a forest fire and its reaction to external factors

The Model

Forest Fire model
control parameters

Grid size	50
Density	0.6





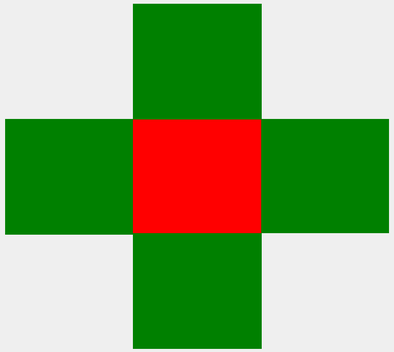
Tree
Burning site
Burned site
Empty site

Wind in the Model

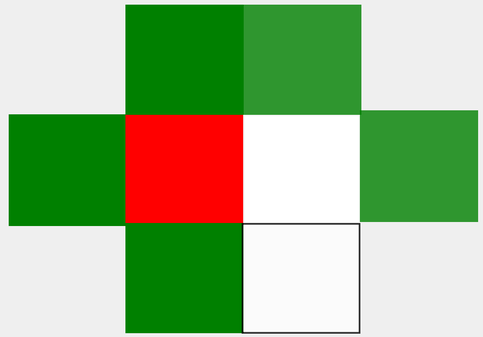
Forest Fire model control parameters

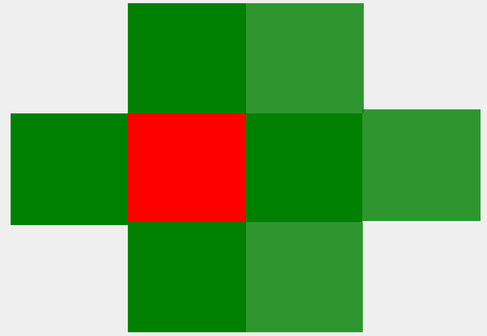
Grid size	50
Density	0.6
Wind	Yes

Neighborhood in the Base Model



Neighborhood in the Wind Model





Wind in the Model

Forest Fire model
control parameters

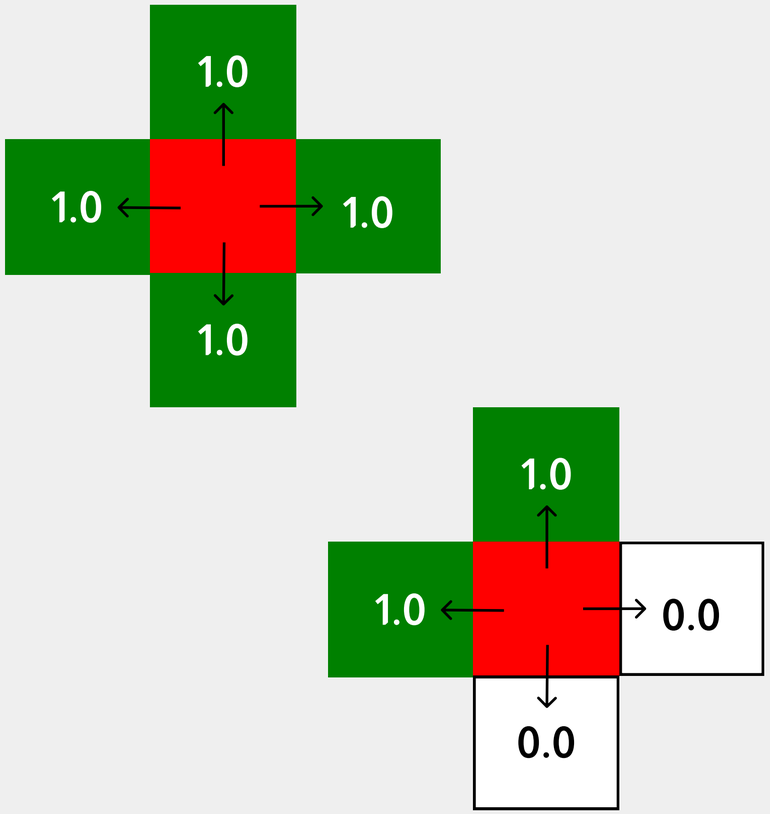
Grid size	50
Density	0.6
Wind	Yes

Spreading Probability in the Model

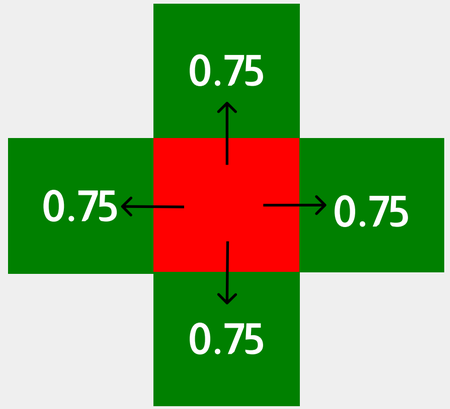
Forest Fire model control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75

Neighborhood in the Base Model



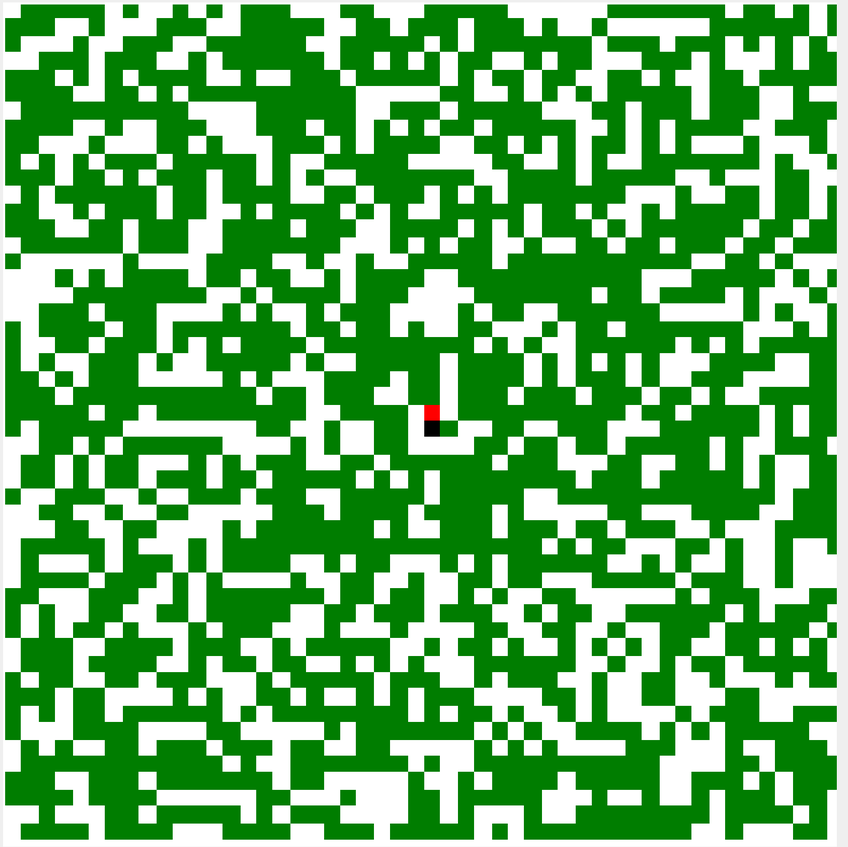
Neighborhood in the probabilistic Model



Spreading Probability in the Model

Forest Fire model
control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75

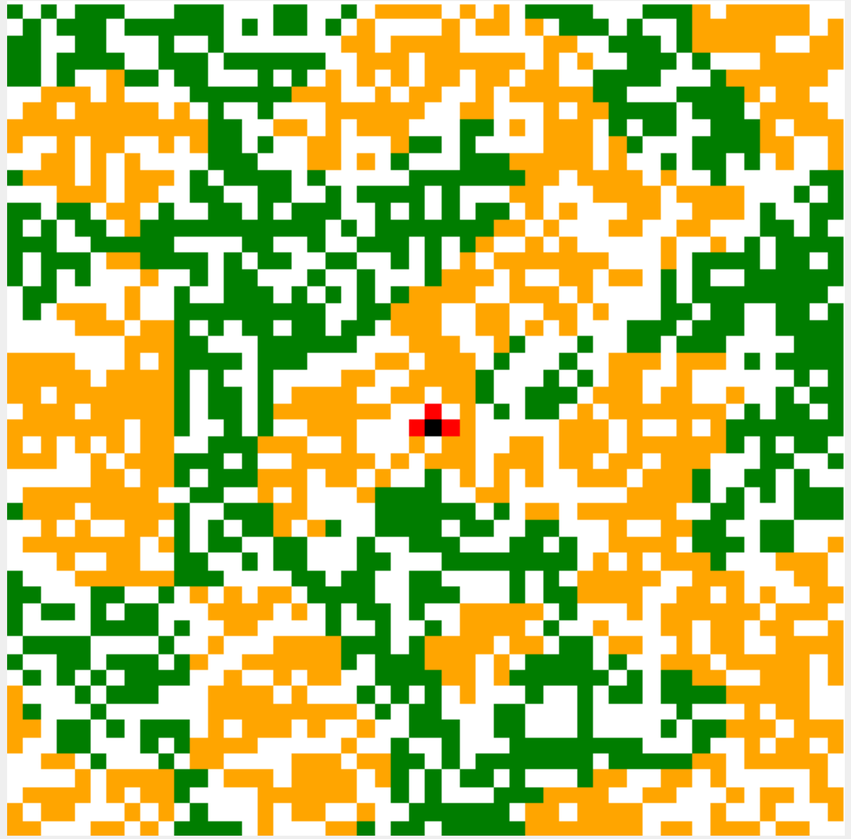


Tree
Burning site
Burned site
Empty site

Types of Vegetation in the Model

Forest Fire model
control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75
Plant tree proportion	0.5



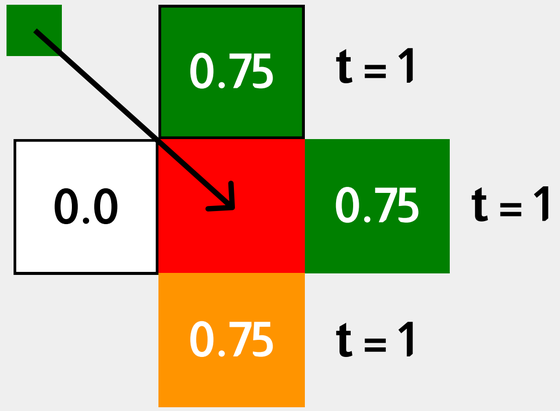
Tree
Plant
Burning site
Burned site
Empty site

Burn Time of Vegetation in the Model

Forest Fire model control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75
Plant tree proportion	0.5
Tree burn time	3
Plant burn time	1

A Burnt Tree has 3 opportunities to Ignite Neighbors



Probability of a tree igniting a neighboring cell
0.75

P_s

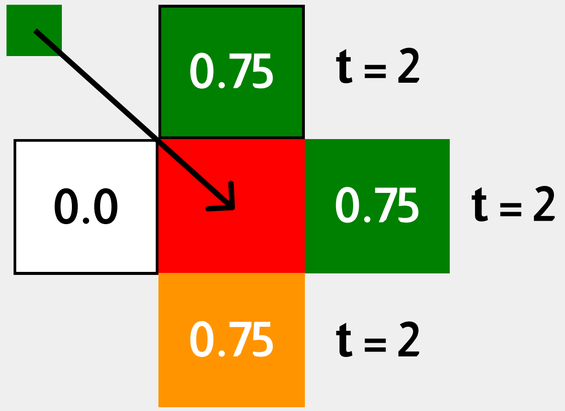
Tree
Plant
Burning site
Burned site
Empty site

Burn Time of Vegetation in the Model

Forest Fire model control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75
Plant tree proportion	0.5
Tree burn time	3
Plant burn time	1

A Burnt Tree has 3 opportunities to Ignite Neighbors



Probability of a tree igniting a neighboring cell
0.75 + 0.75(1-0.75) = 0.9375

$$P_s + P_s(1 - P_s)^{i-1}$$

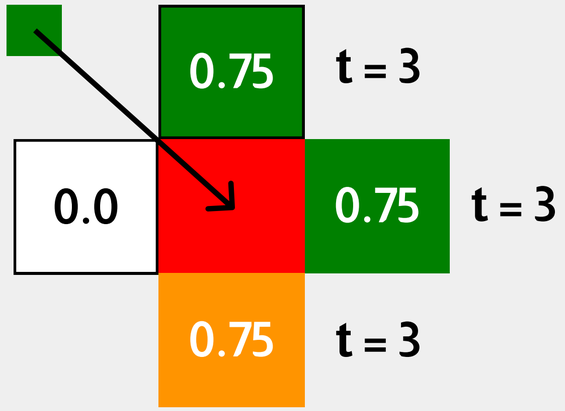
Tree
Plant
Burning site
Burned site
Empty site

Burn Time of Vegetation in the Model

Forest Fire model control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75
Plant tree proportion	0.5
Tree burn time	3
Plant burn time	1

A Burnt Tree has 3 opportunities to Ignite Neighbors



Probability of a tree igniting a neighboring cell

0.9375 + 0.75(1-0.75)^2 = 0.98

$$\sum_{i=1}^{\Delta_{tree}} P_s(1-P_s)^{i-1}$$

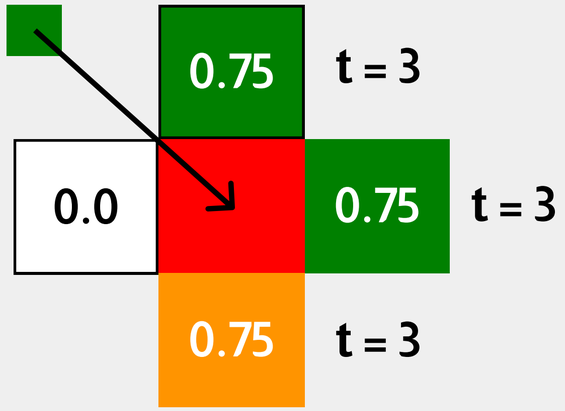
Tree
Plant
Burning site
Burned site
Empty site

Burn Time of Vegetation in the Model

Forest Fire model control parameters

Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75
Plant tree proportion	0.5
Tree burn time	3
Plant burn time	1

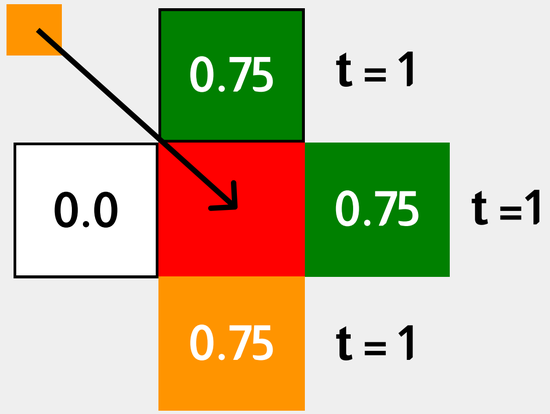
A Burnt Tree has 3 opportunities to Ignite Neighbors

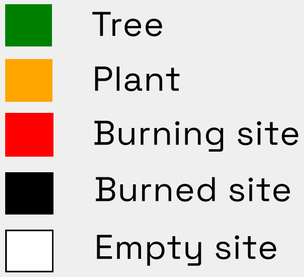


General

$$\sum_{i=1}^{\Delta_{tree}} P_s(1-P_s)^{i-1}$$

A Burnt Plant has 1 opportunity to Ignite Neighbors

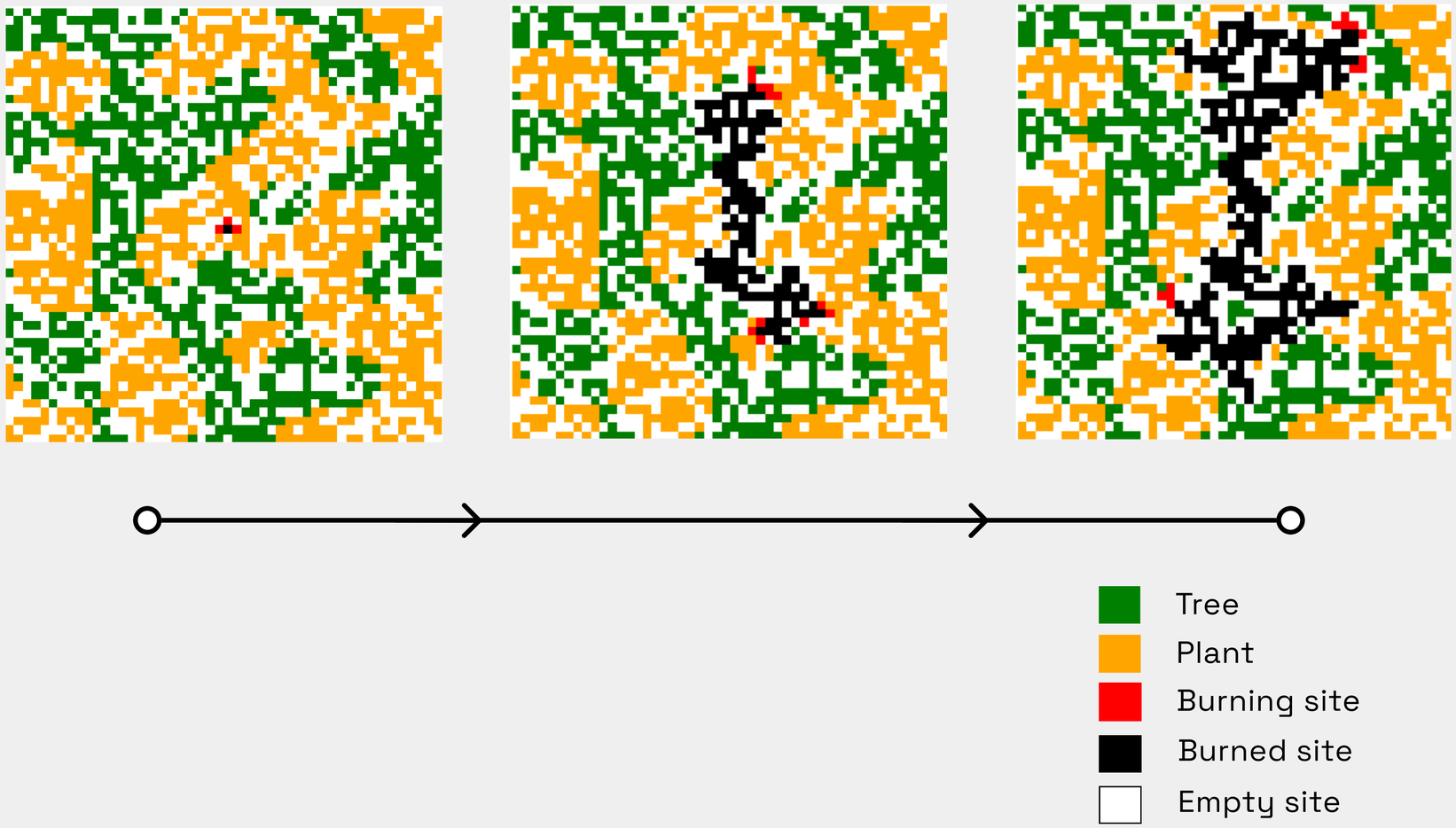




Vegetation Noise in the Model

Forest Fire model
control parameters

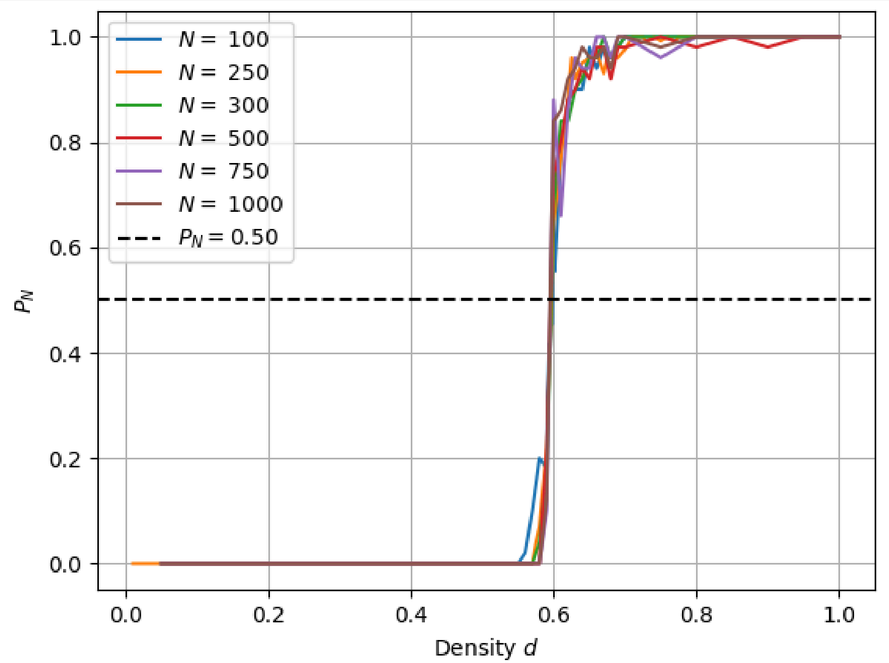
Grid size	50
Density	0.6
Wind	No
Spreading probability	0.75
Plant tree proportion	0.5
Tree burn time	3
Plant burn time	1

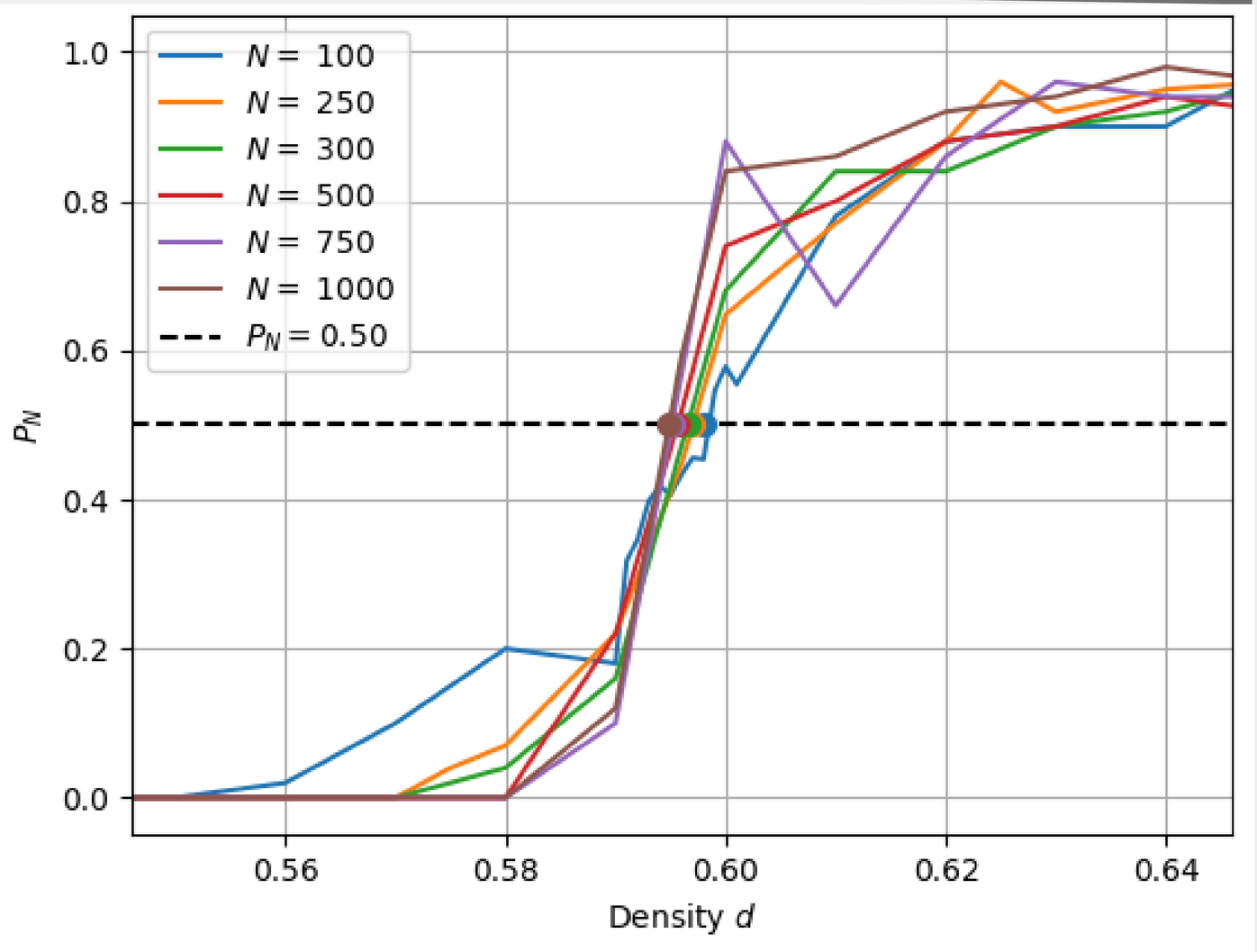


Results

Percolation, Critical Densities and Behavior at the Critical Density

Percolation Base Model

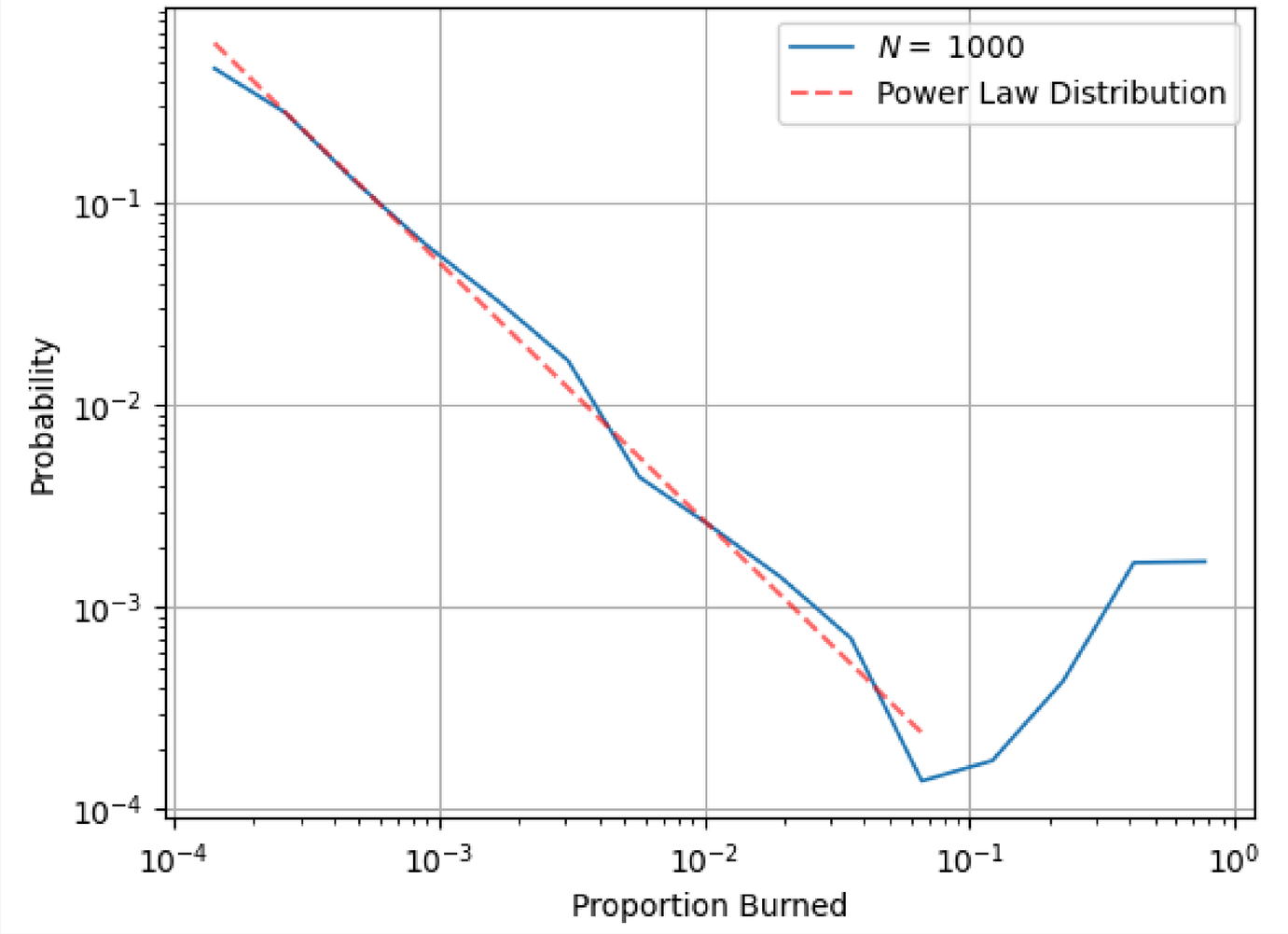




Wind ~ No
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Von Niessen, W., & Blumen, A. (1986)

Behavior at the Critical Density



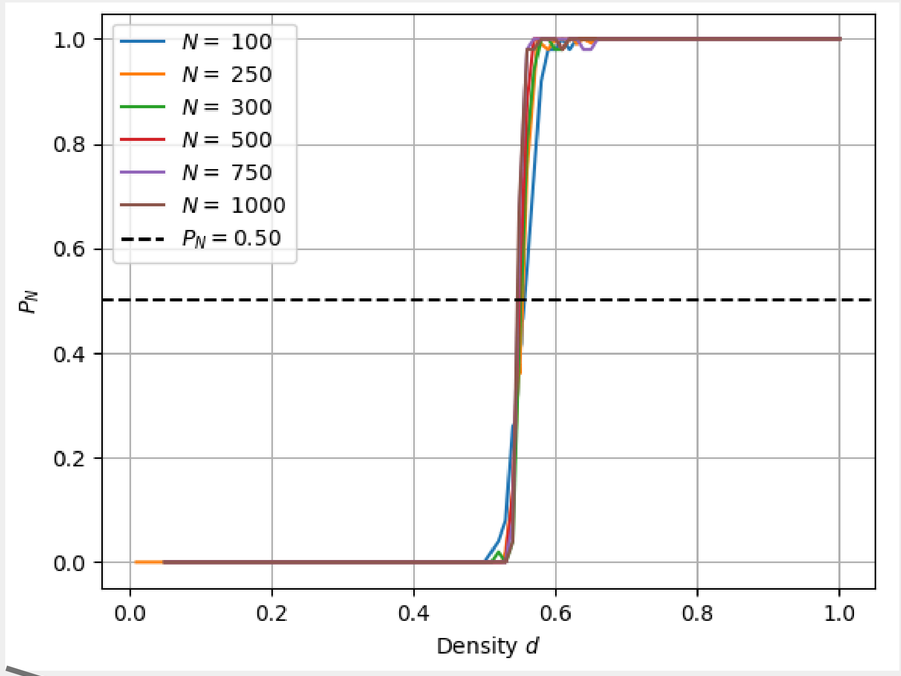
Wind ~ No
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

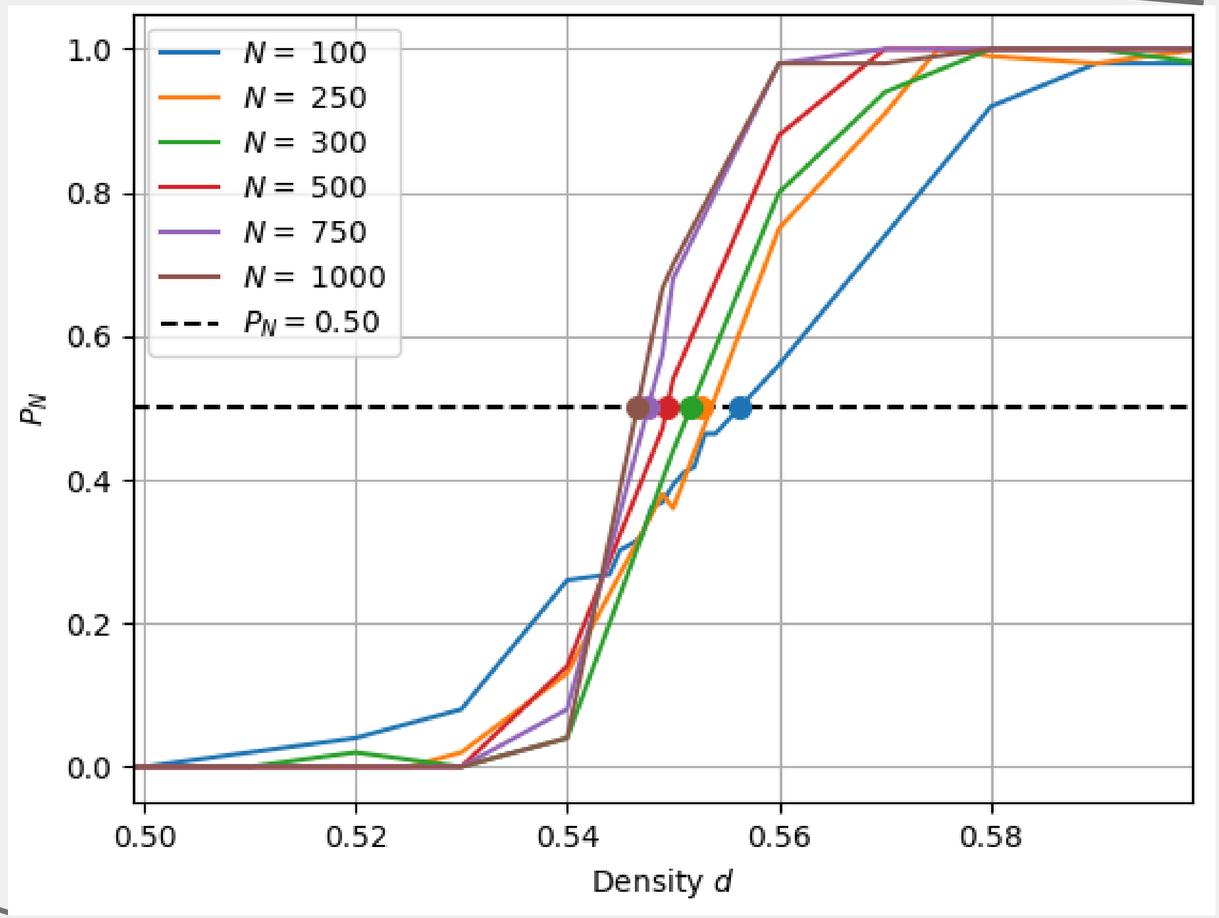
Critical Density

~ 0.596

KS Test
KS = 0.236
P-value = 0.778 > 0.05

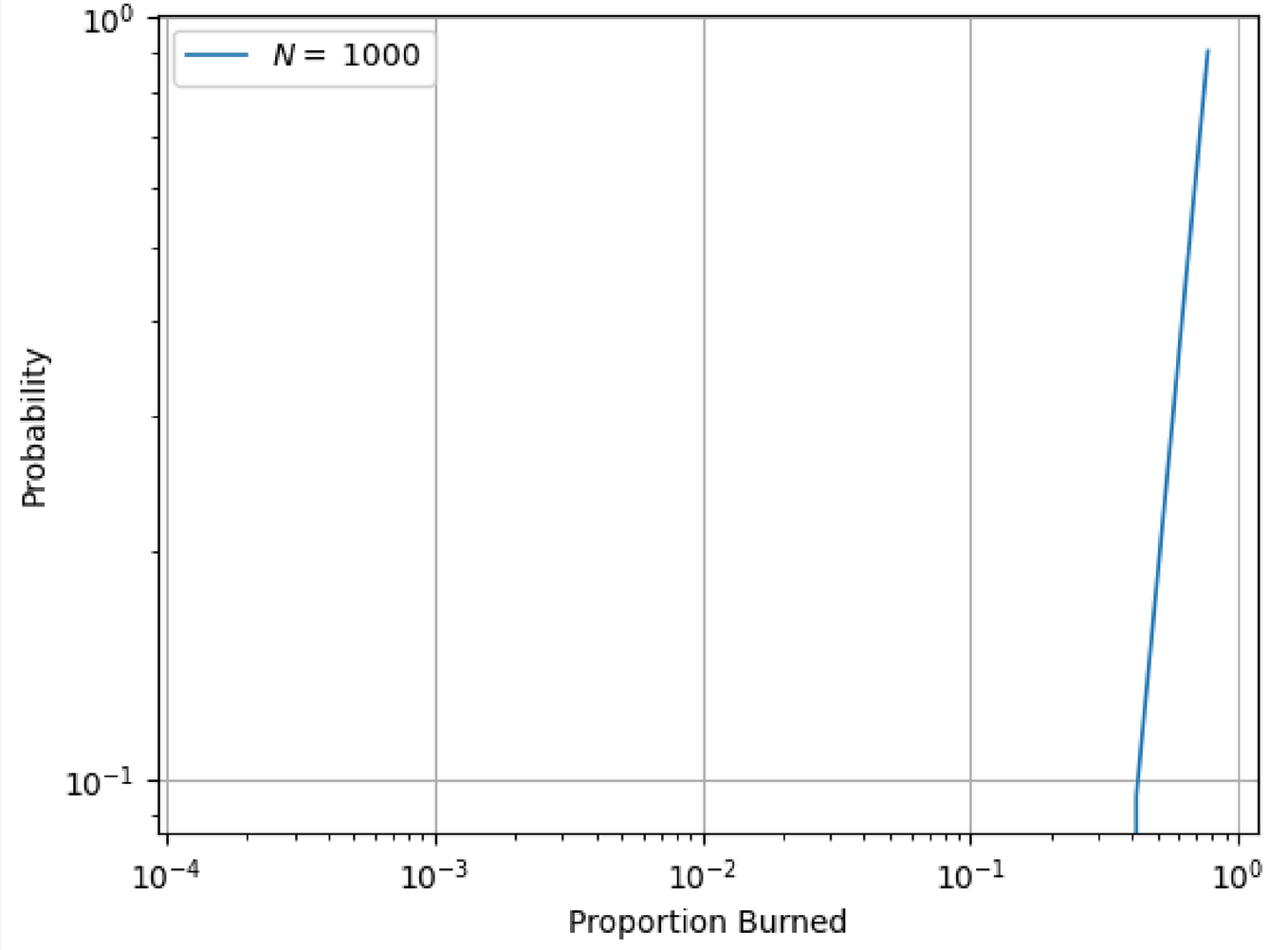
Effect on Percolation of Adding **Wind** to the Model





Wind ~ Yes
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Behavior at the Critical Density

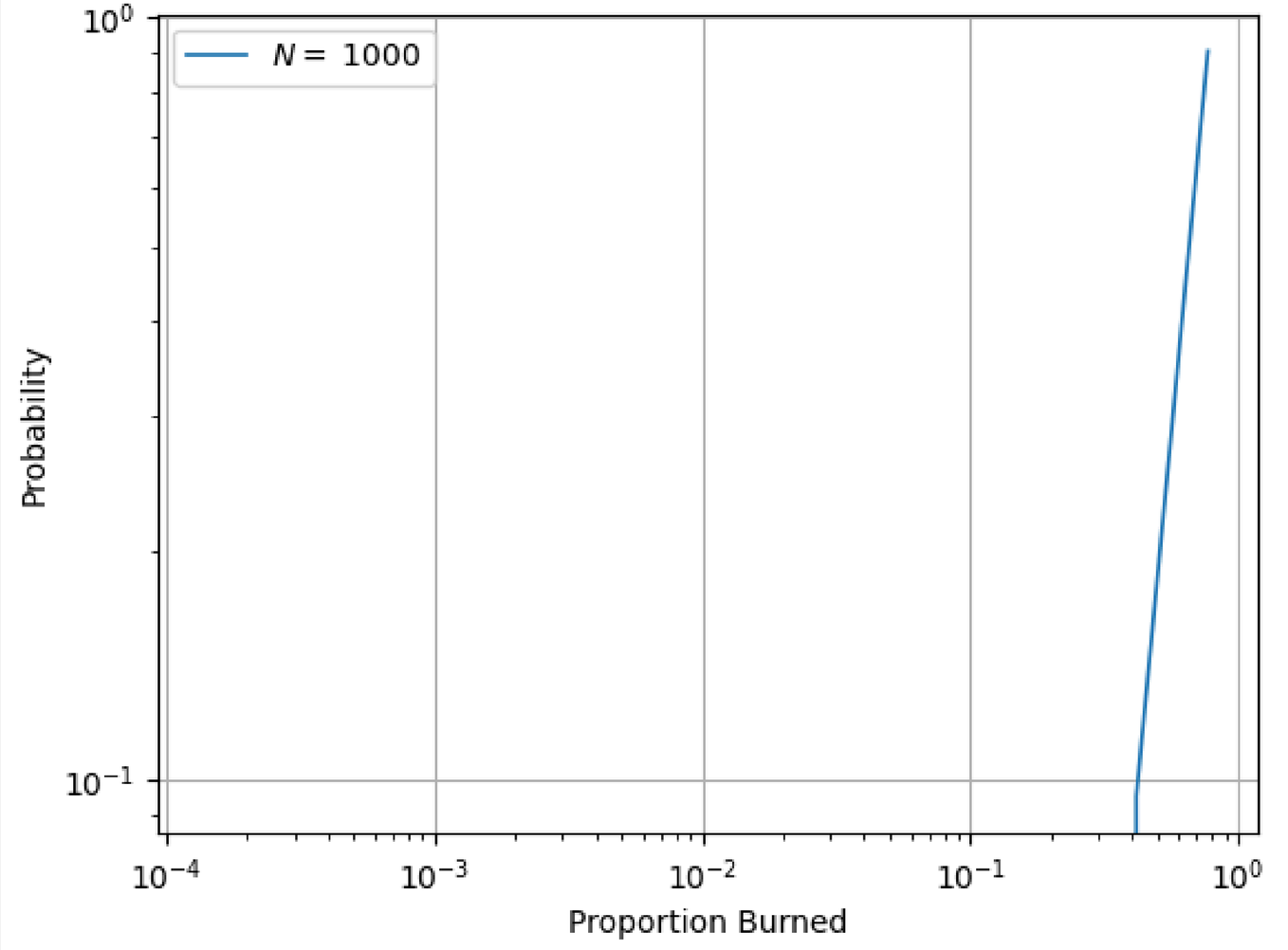


Critical Density

~ 0.549

Wind ~ Yes
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Behavior at the Critical Density

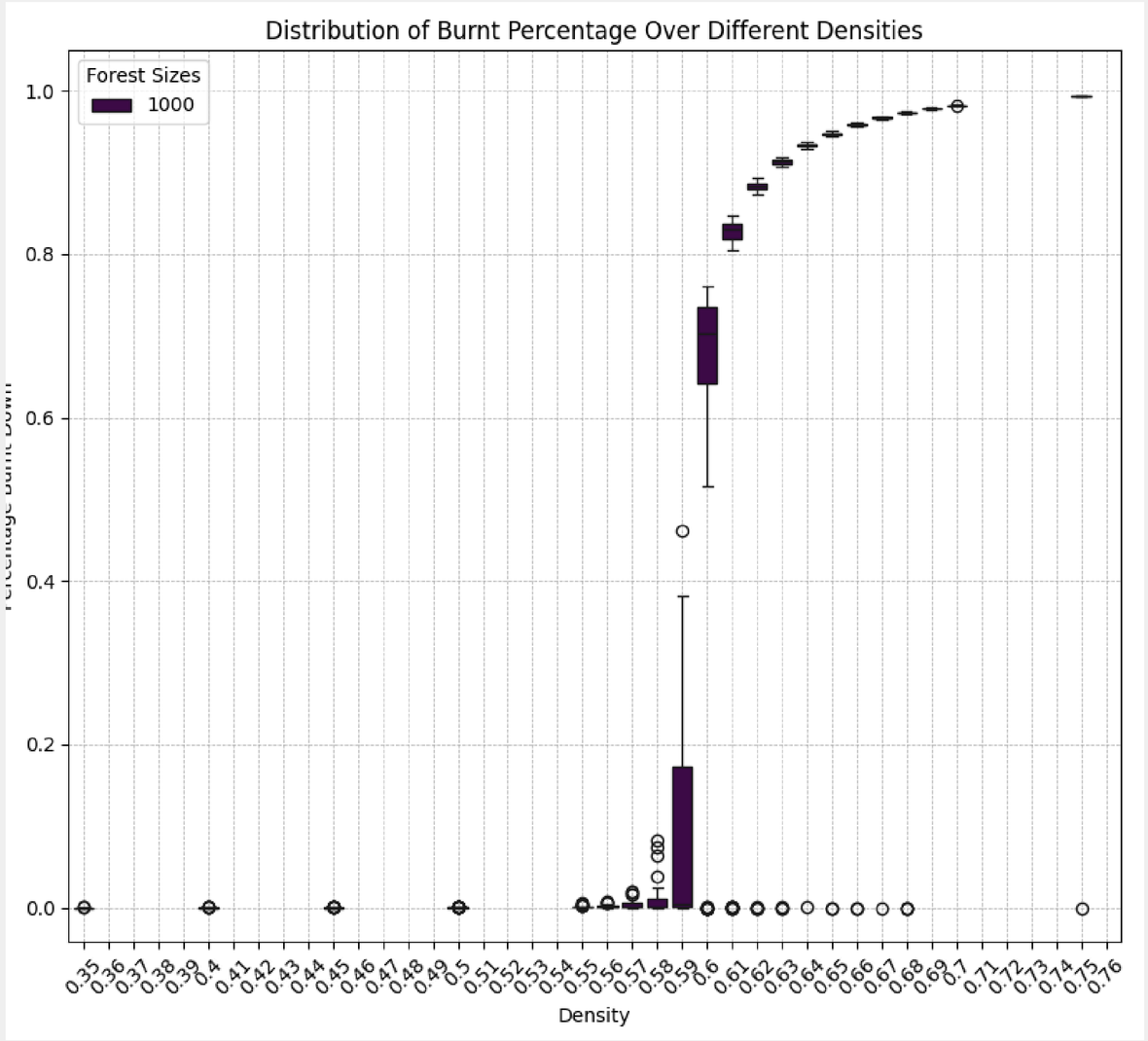


Wind ~ Yes
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

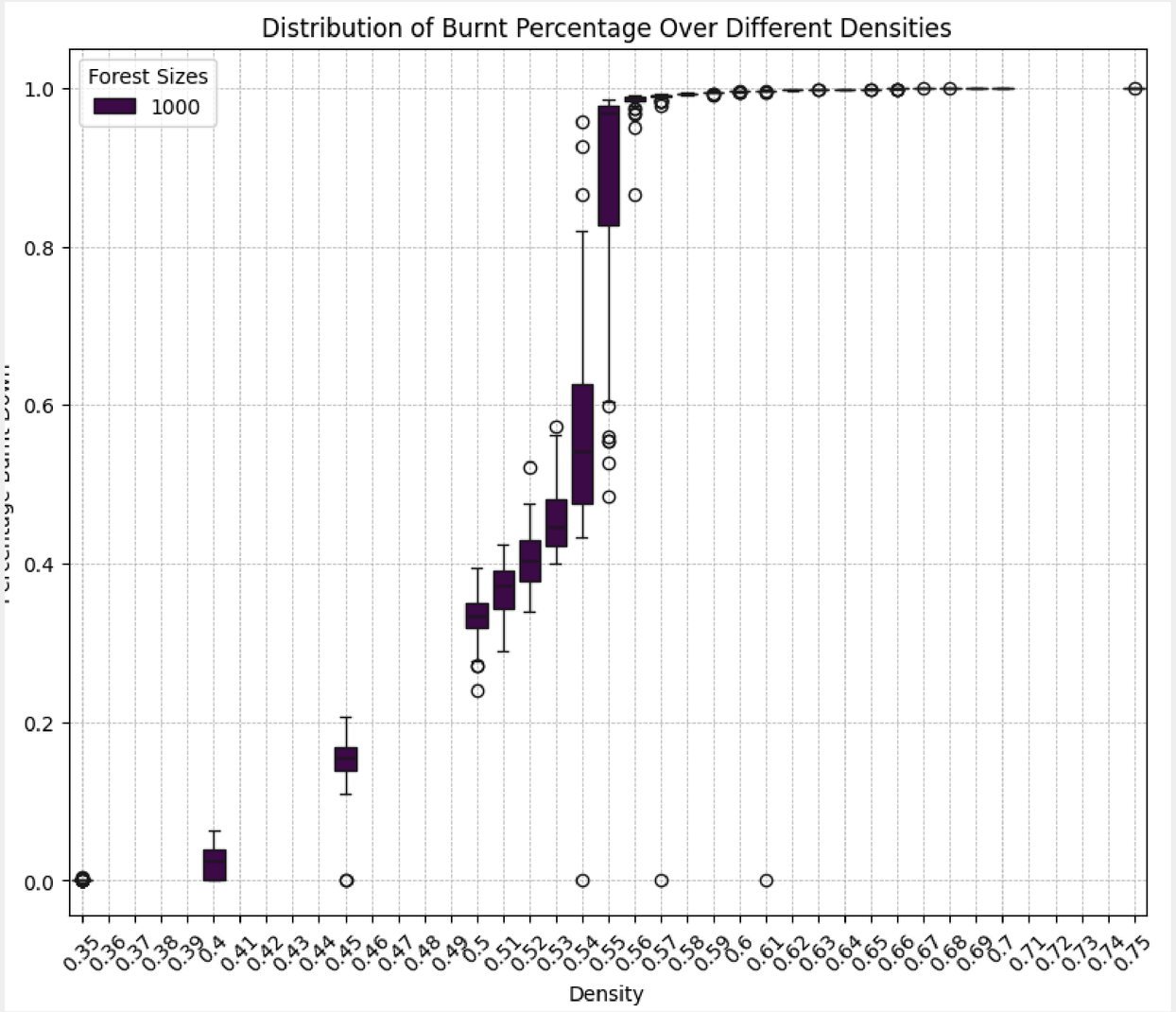
~~**Critical Density**~~
~~~ 0.549~~

KS Test
No power law fit
~~~

Variance in the Wind Model

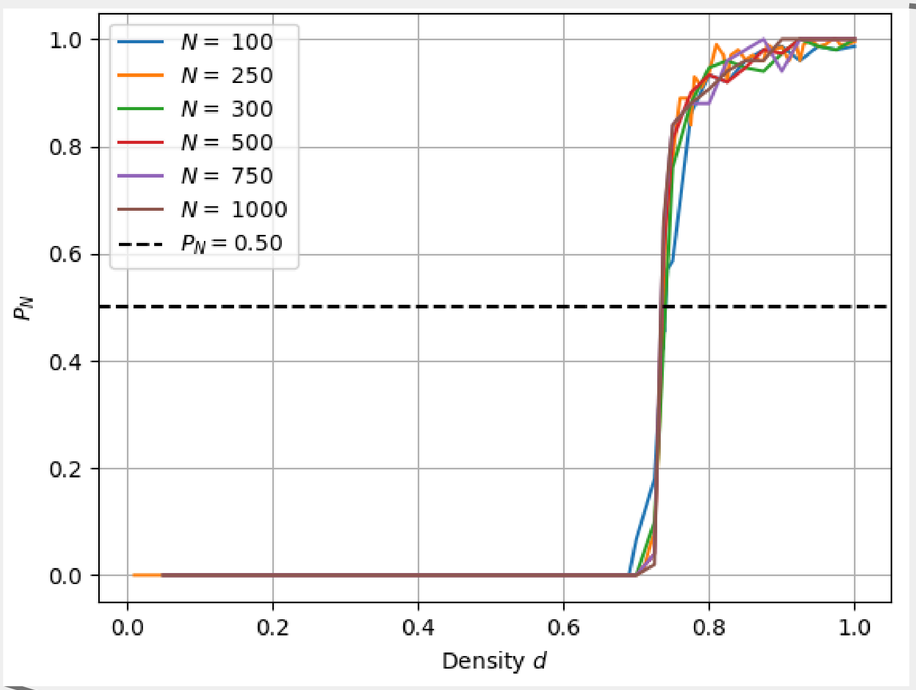
Base Model

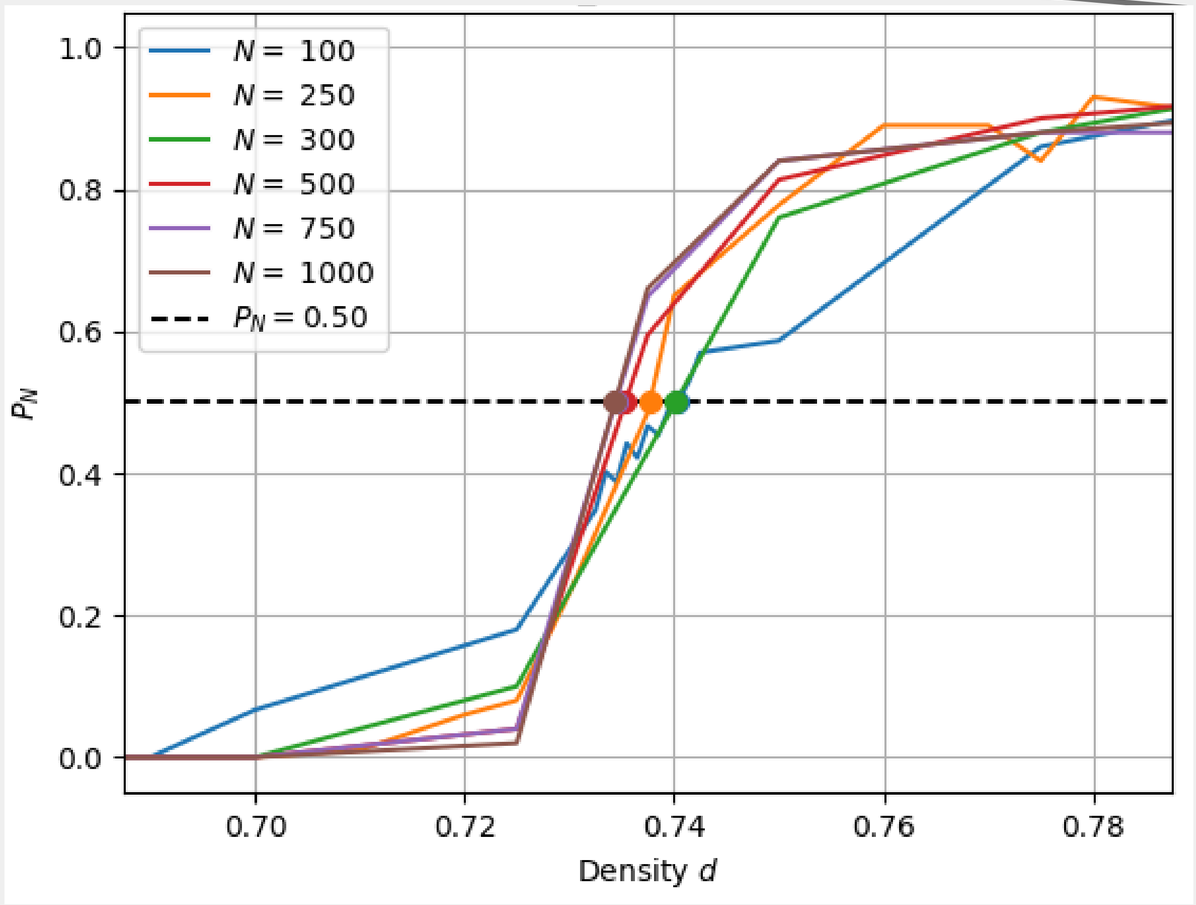


Wind Model



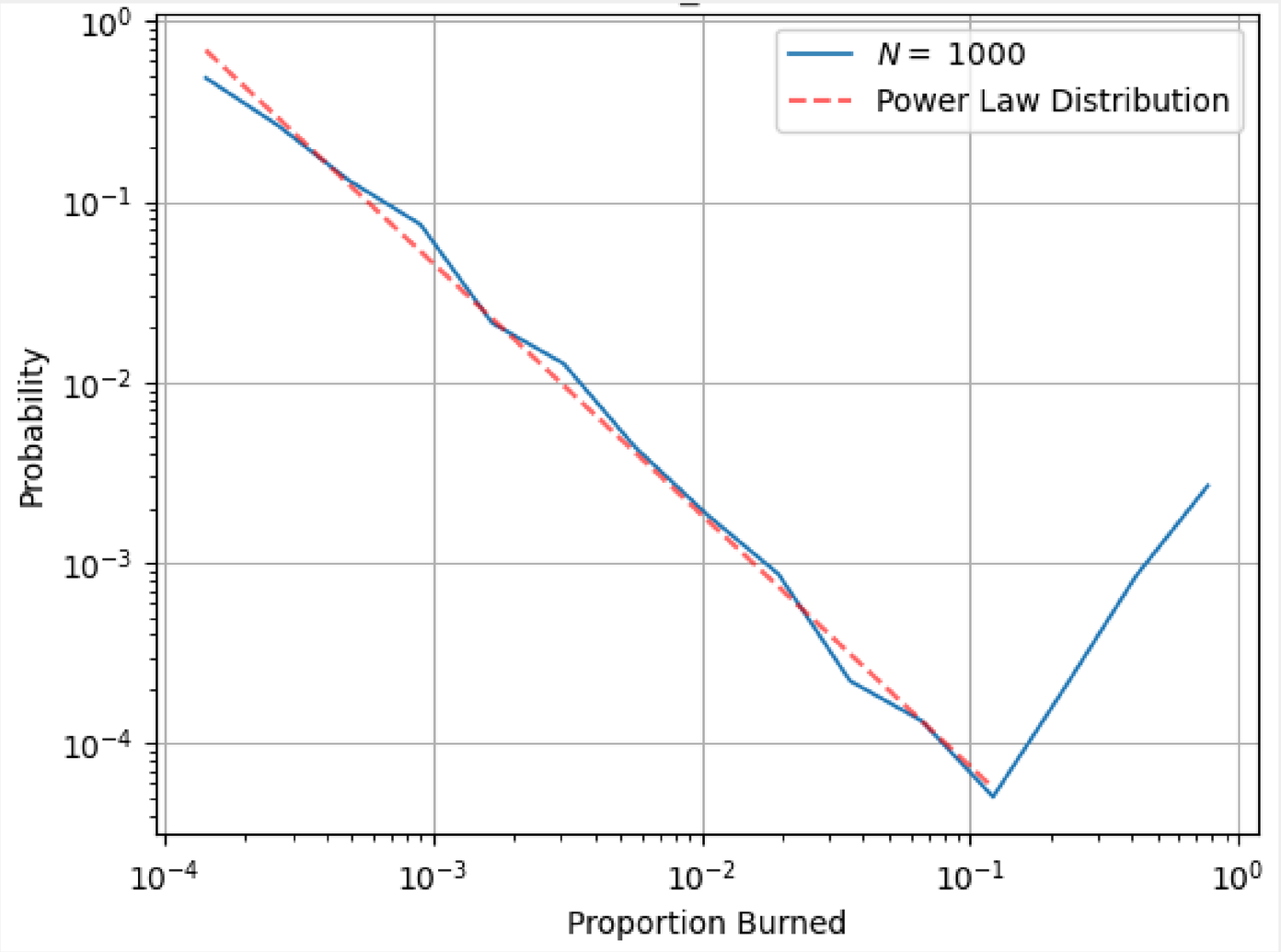
Effect on Percolation of Adding **Probability** to the Model





Wind ~ No
P ~ 0.75
Plant/Tree ~ 0
ΔTree ~ 1

Behavior at the Critical Density



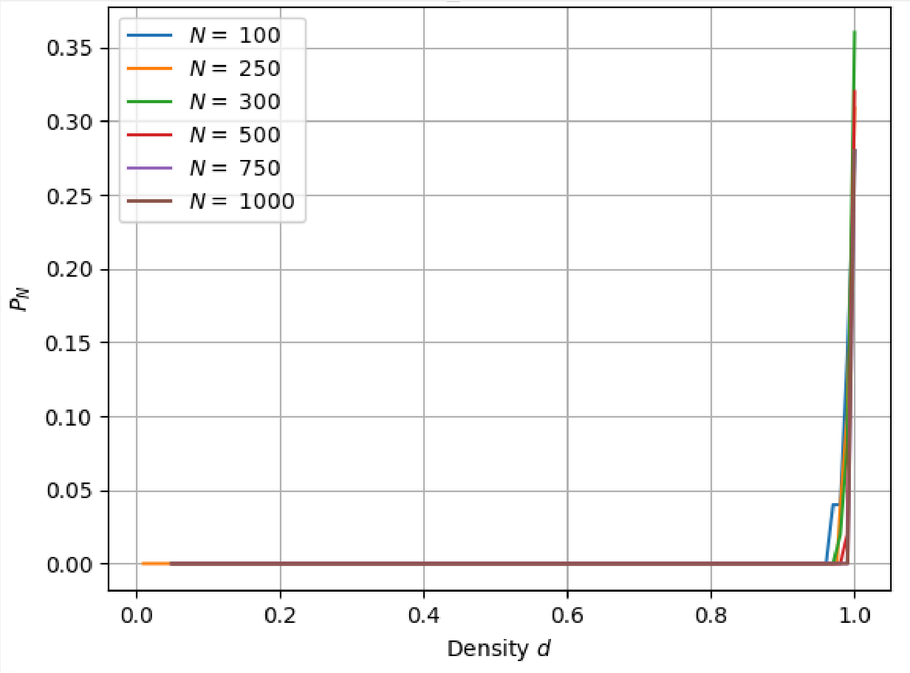
Wind ~ No
P ~ 0.75
Plant/Tree ~ 0
ΔTree ~ 1

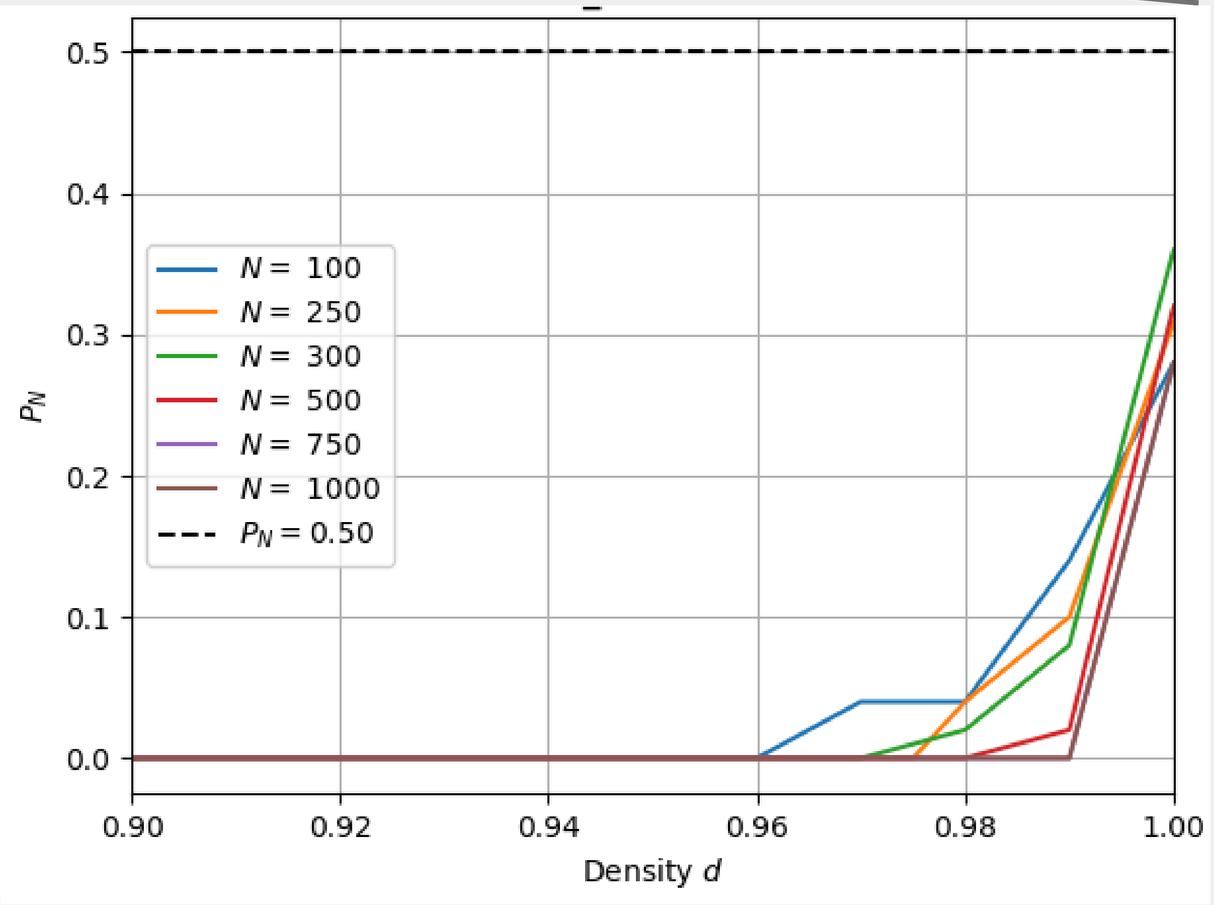
Critical Density

~ 0.7375

KS Test
KS = 0.15
P-value = 0.990 > 0.05

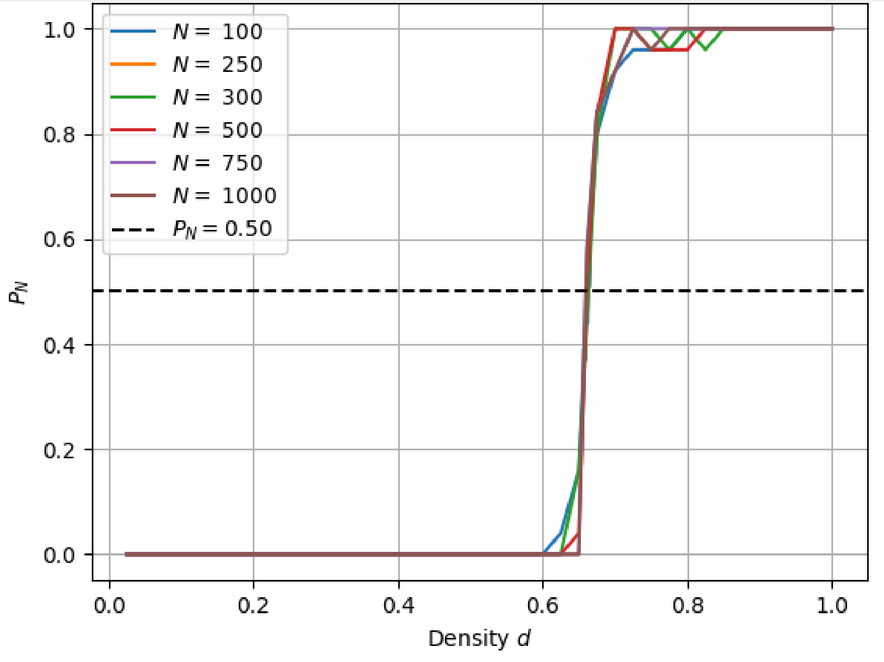
Effect on Percolation of Adding **Probability** to the Model

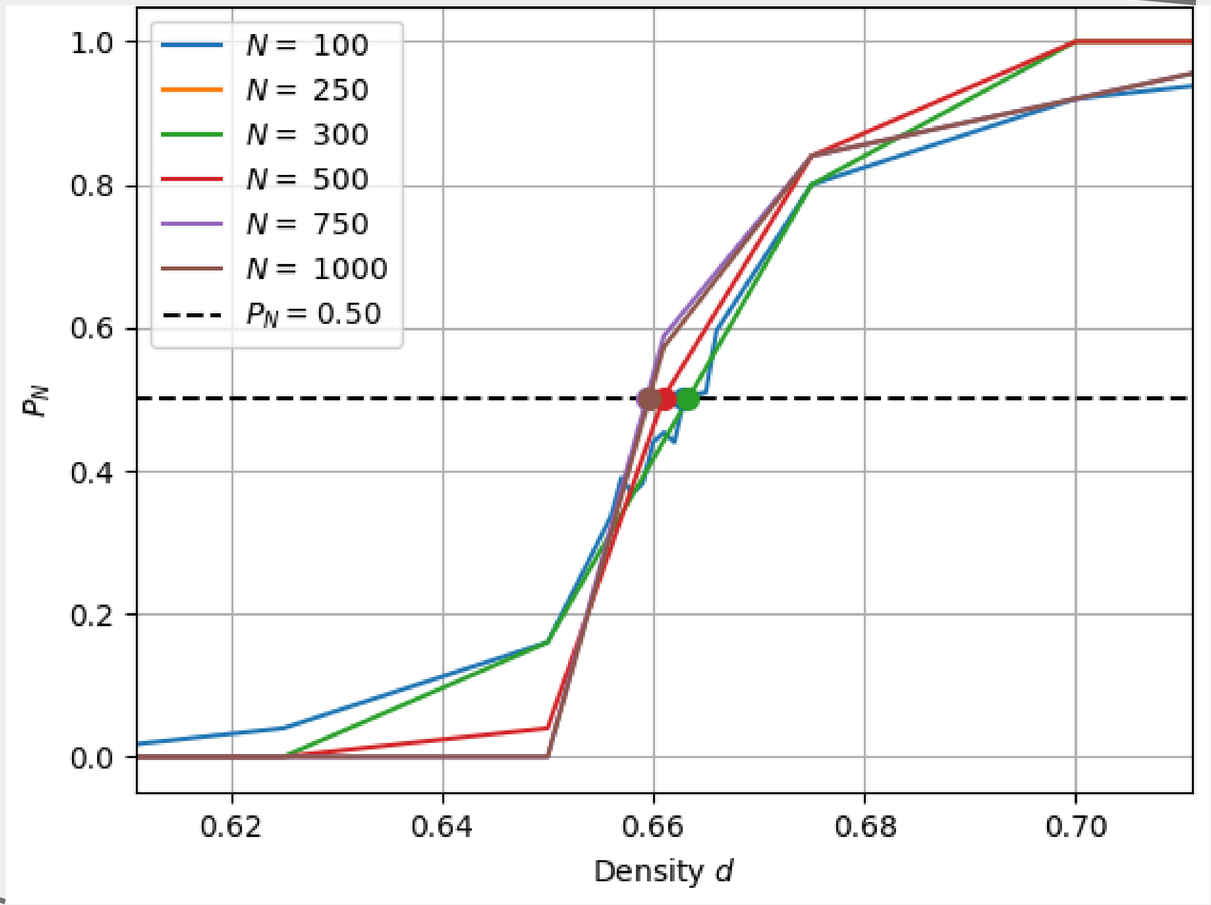




Wind ~ No
P ~ 0.5
Plant/Tree ~ 0
ΔTree ~ 1

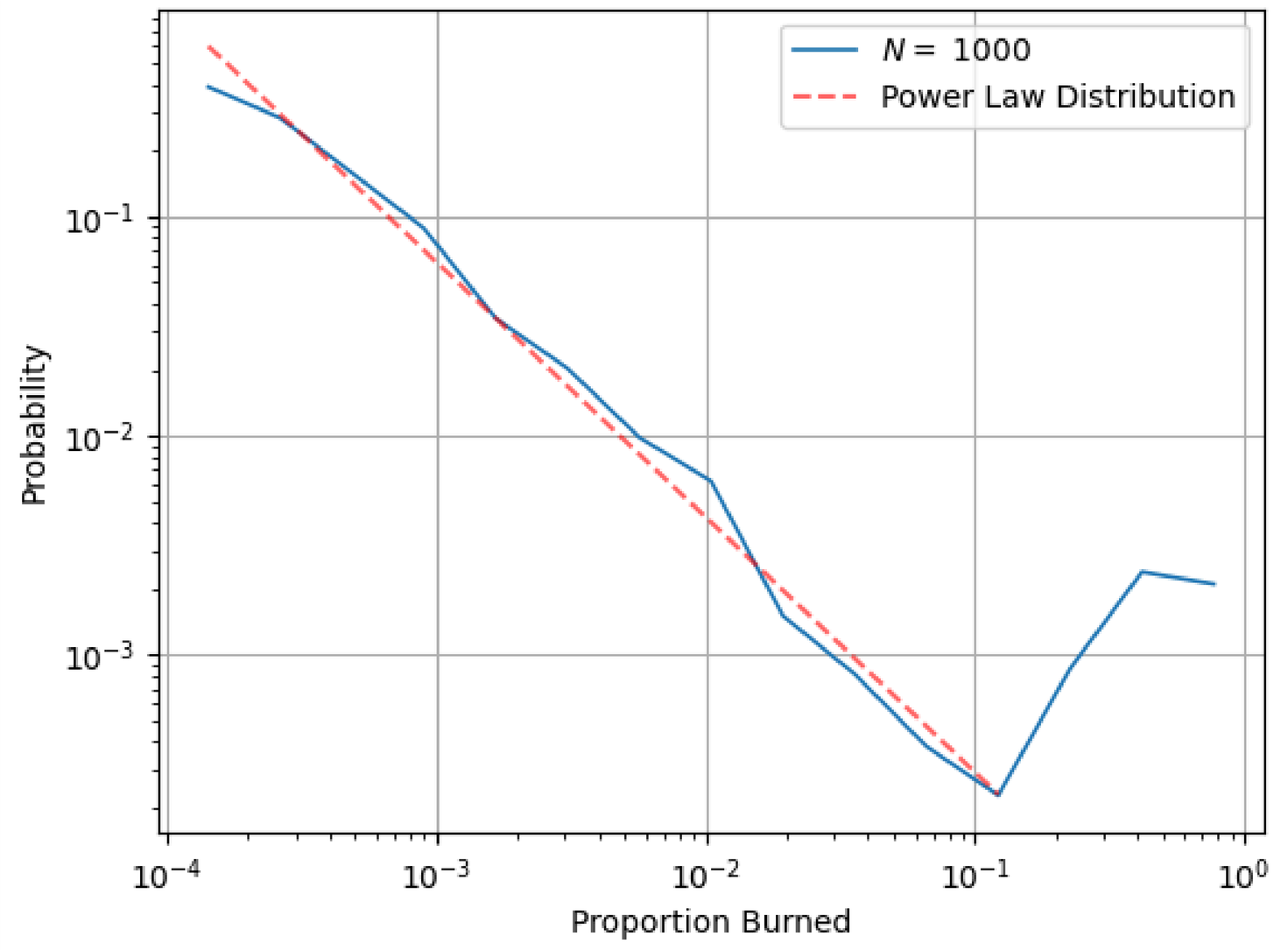
Effect on Percolation of Adding **Vegetation types** to the Model





Wind ~ No
P ~ 0.75
Plant/Tree ~ 0.5
ΔTree ~ 3
ΔPlant ~1

Behavior at the Critical Density



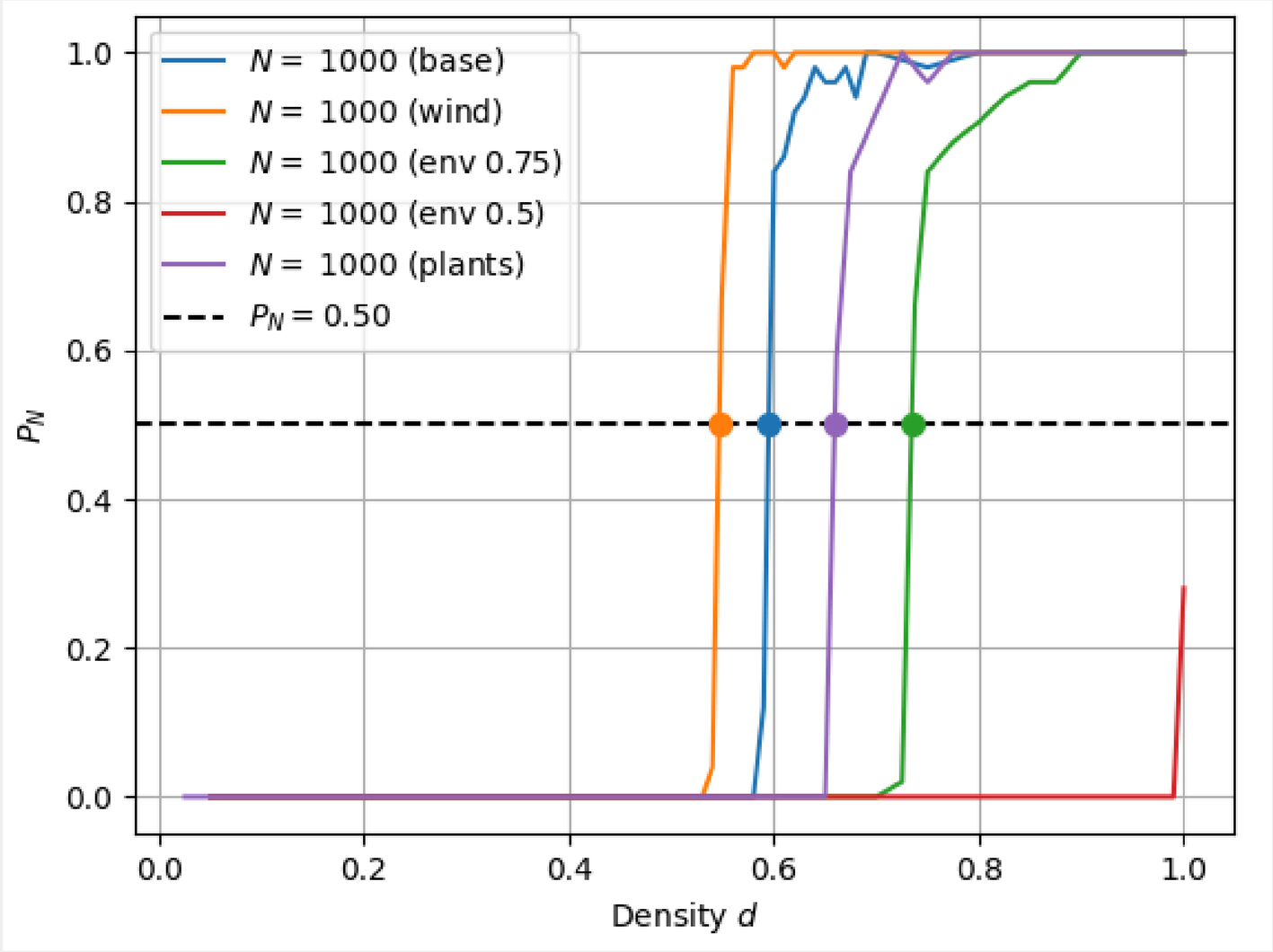
Wind ~ No
P ~ 0.75
Plant/Tree ~ 0.5
ΔTree ~ 3
ΔPlant ~1

Critical Density

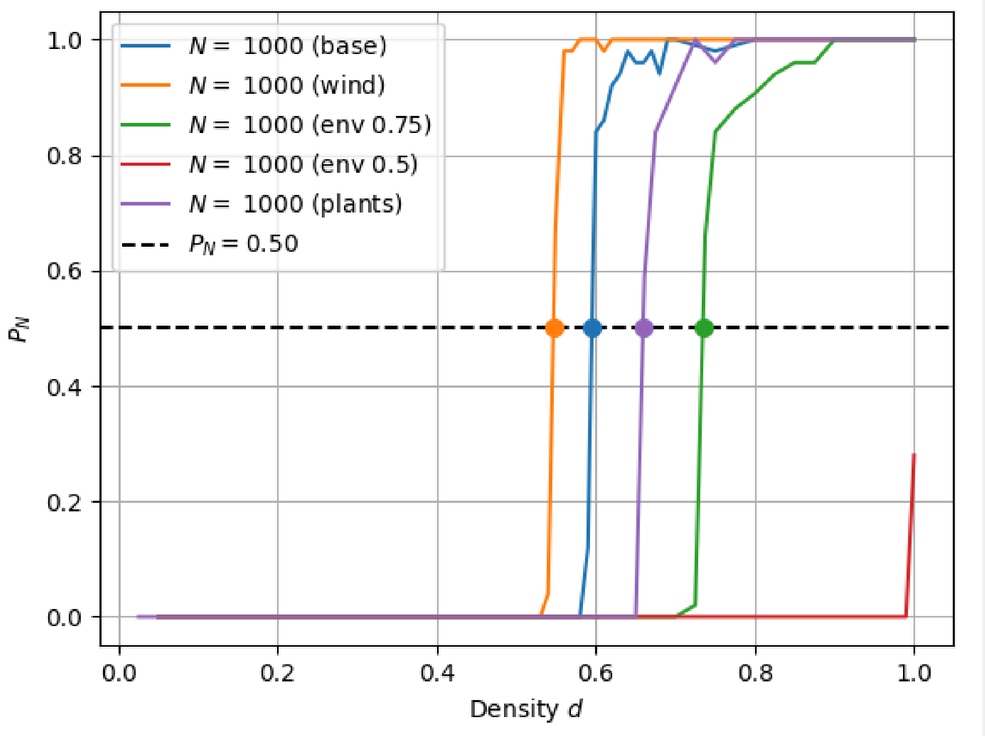
~ 0.661

KS Test
KS = 0.15
P-value = 0.990 > 0.05

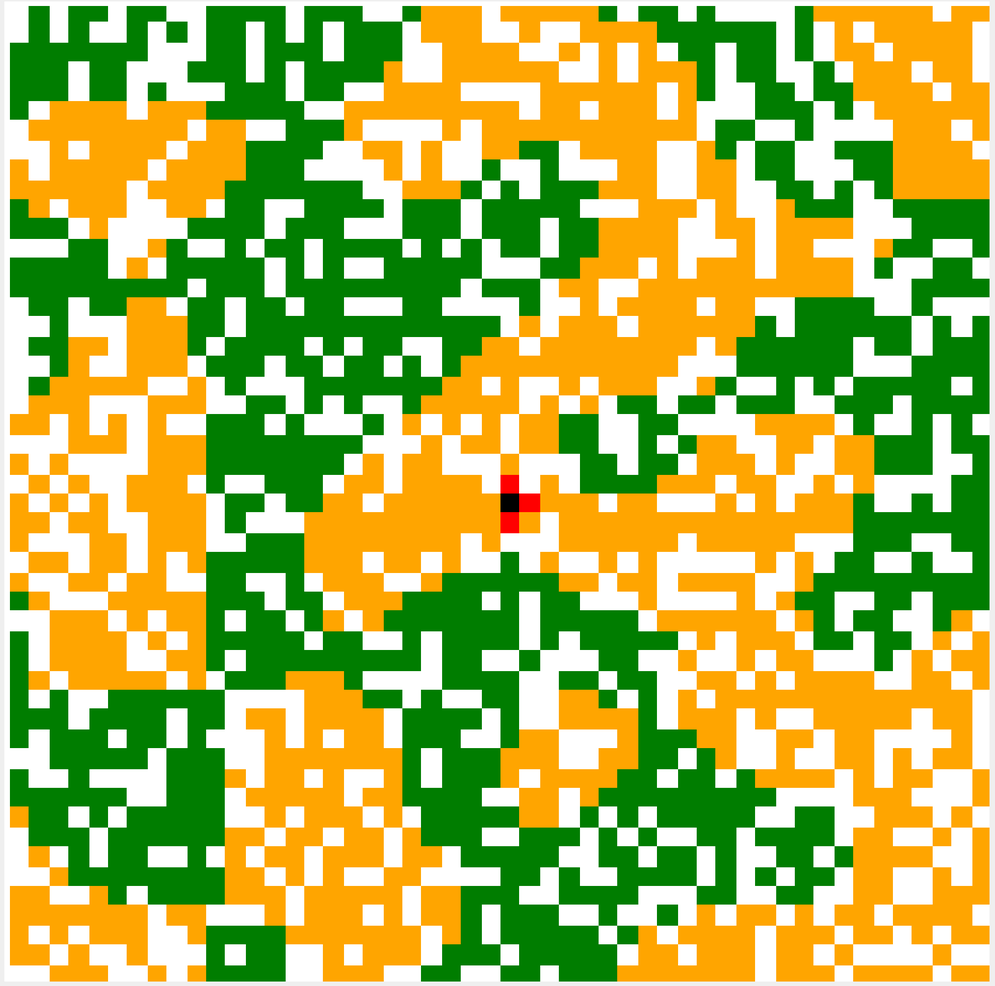
Comparing the different systems



Conclusions



1	Do forest fires exhibit characteristics of criticality? **The forest fire model exhibits characteristics of criticality!**
2	How does introducing wind into the system affect the critical density and does it still exhibit criticality? **Including wind in the system breaks the criticality**
3	How do environmental influences affect the critical density and does it still exhibit criticality? **Lowering the spreading probability makes the critical density shift towards 1.0 before disappearing**
4	How does a combination of a variety of burnable vegetation and environmental influences affect the critical density and does it still exhibit criticality? **Adding longer-burning vegetation makes the critical density shift back toward base model**



APPENDIX

Bibliography

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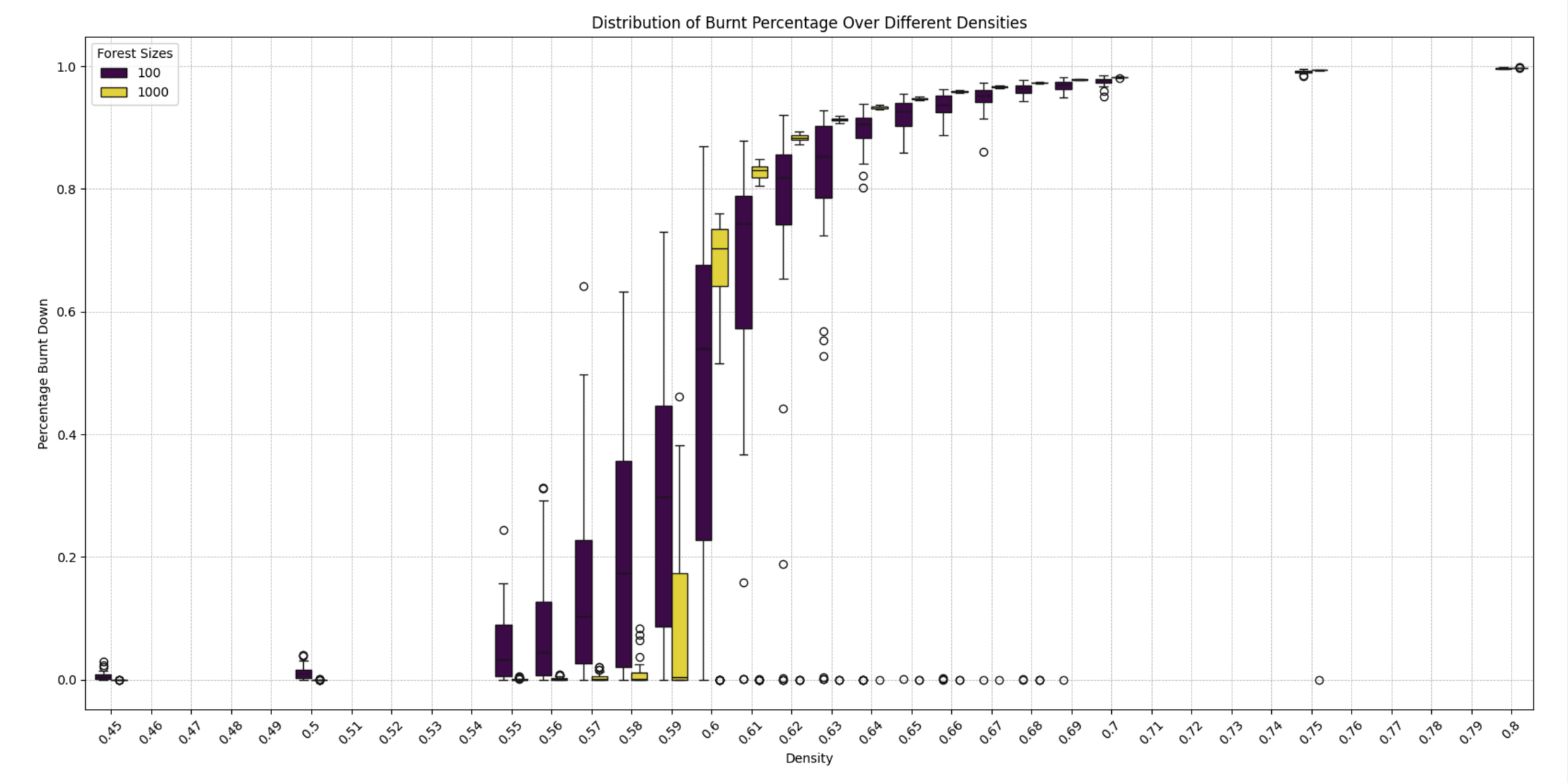
Perestrelo, S. A., Grácio, M. C., Ribeiro, N. D. A., & Lopes, L. M. (2022). A multi-scale network with percolation model to describe the spreading of forest fires. Mathematics, 10(4), 588.

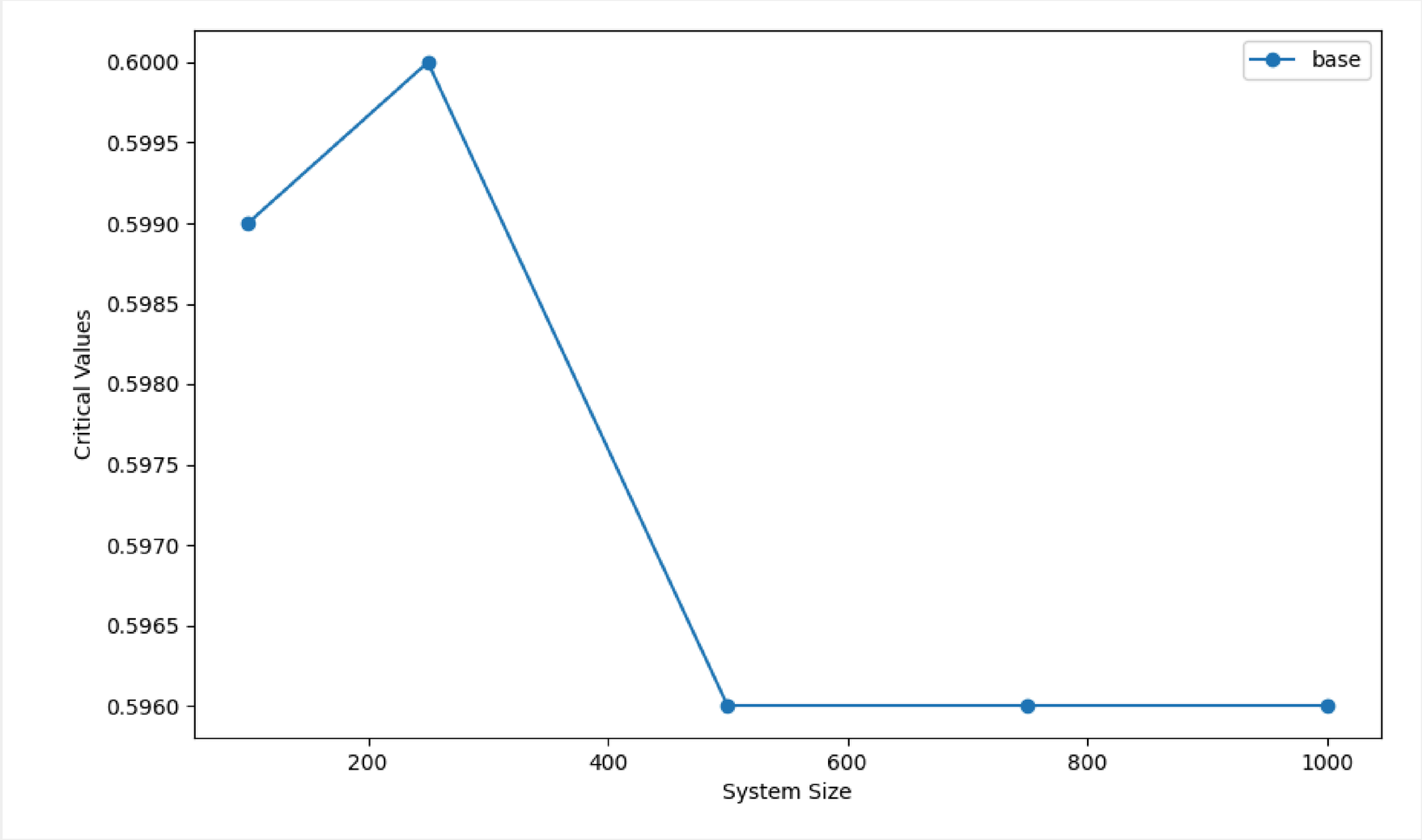
Von Niessen, W., & Blumen, A. (1986). Dynamics of forest fires as a directed percolation model. Journal of Physics A: Mathematical and General, 19(5), L289.

Burnt Percentage Variance Base Model



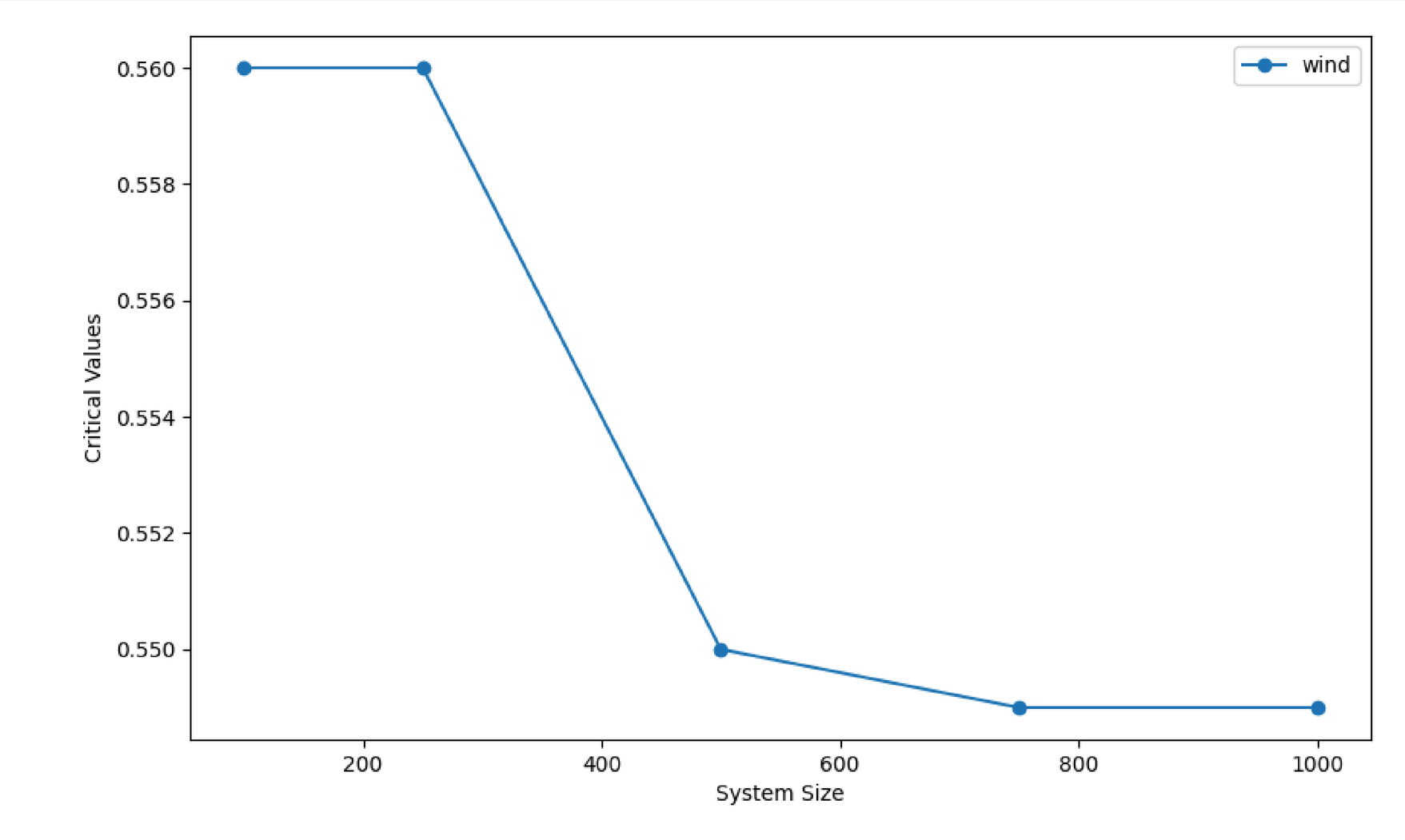
Wind ~ No
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Critical Density over System Size for Base Model



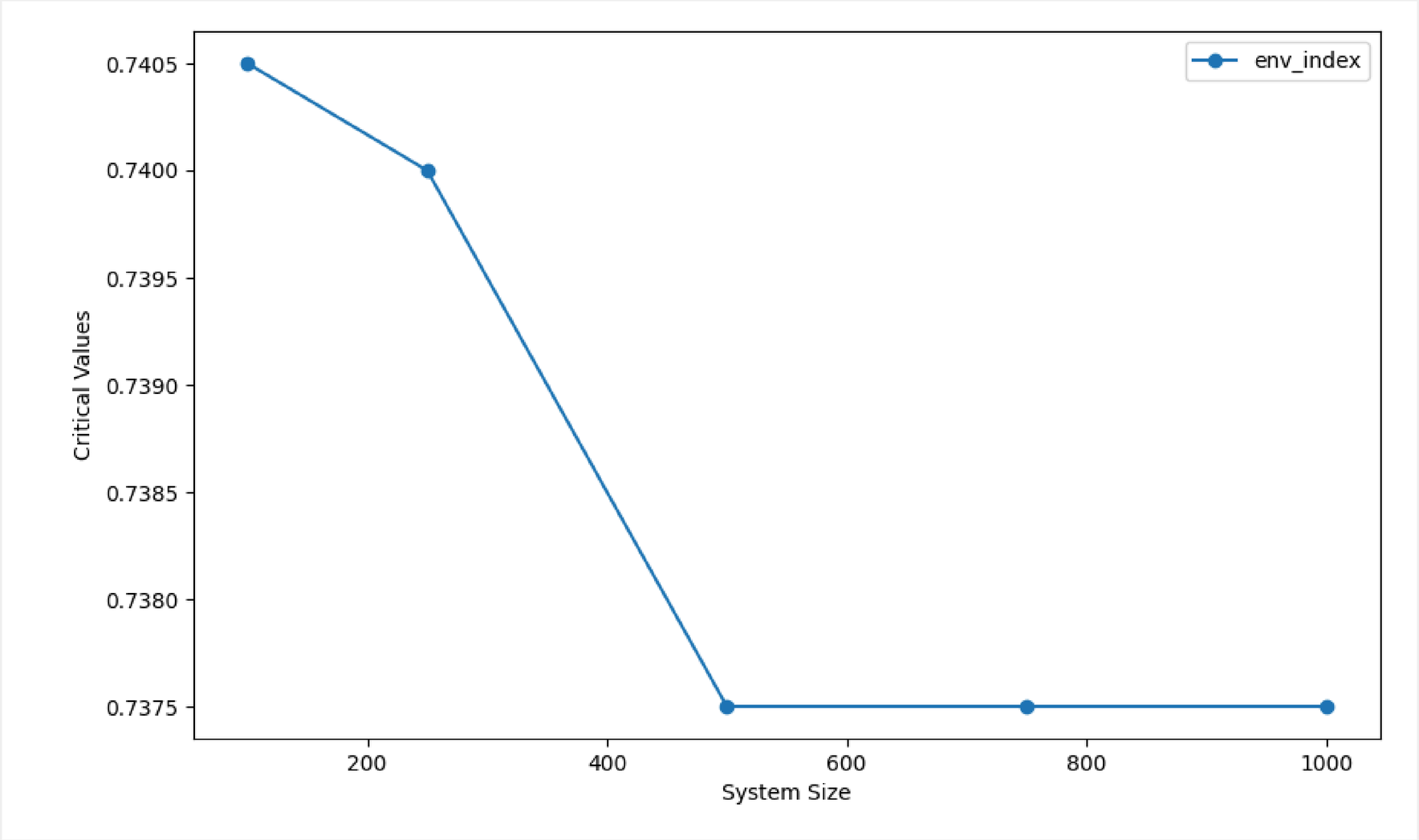
Wind ~ No
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Critical Density for Base Model with Wind



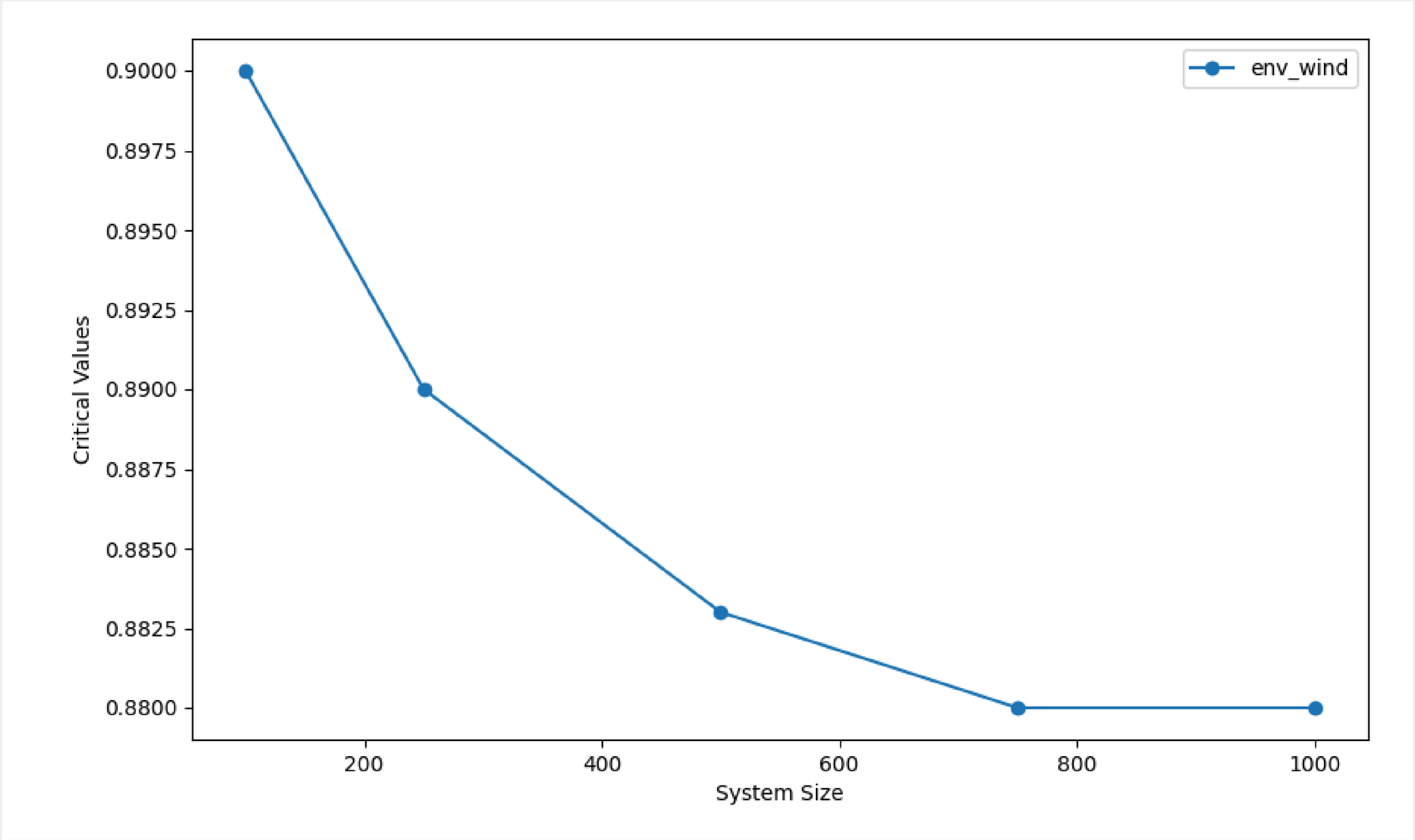
Wind ~ Yes
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Critical Density for Env Index 0.75



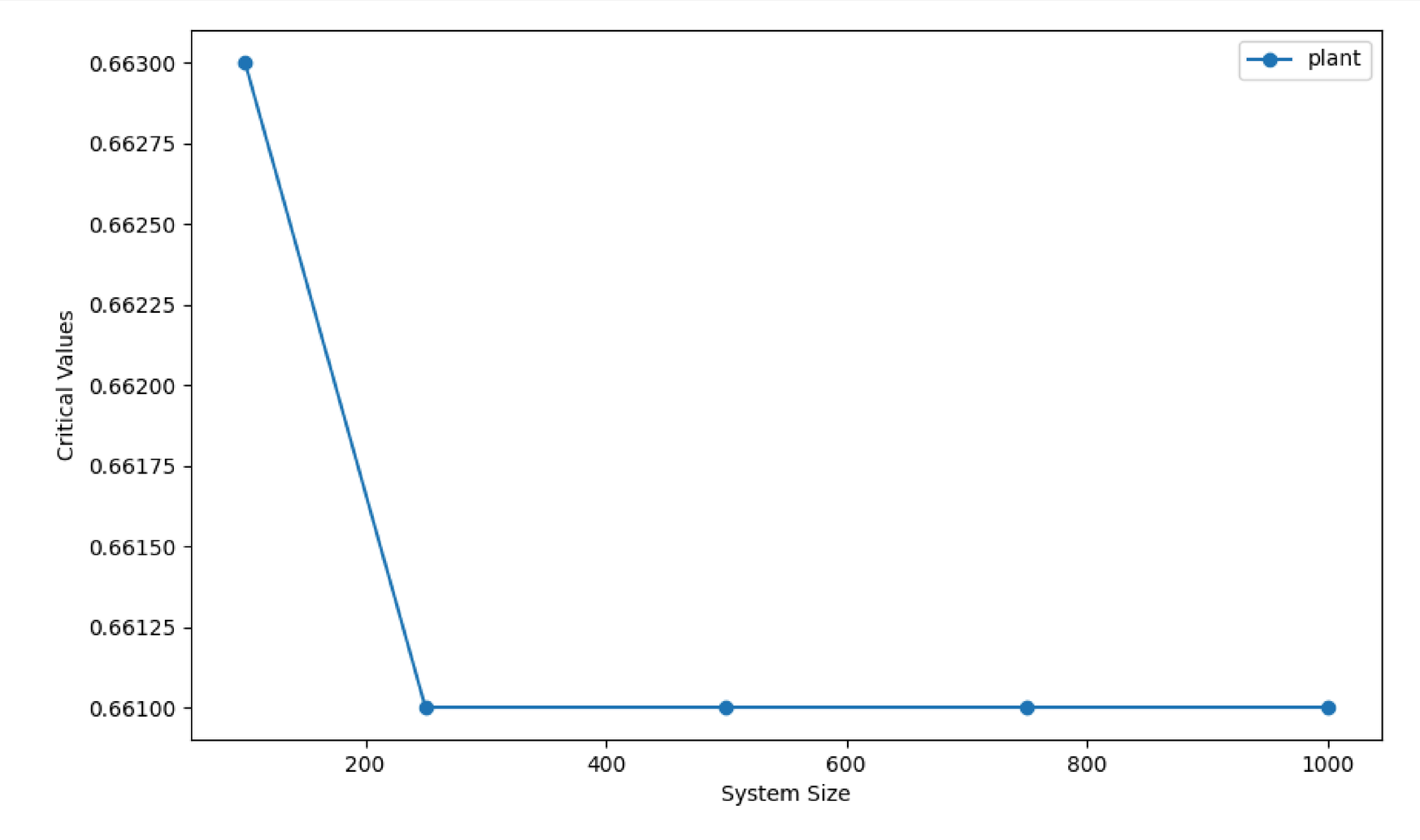
Wind ~ No
P ~ 0.75
Plant/Tree ~ 0
ΔTree ~ 1

Critical Density for Env Index 0.5 with Wind



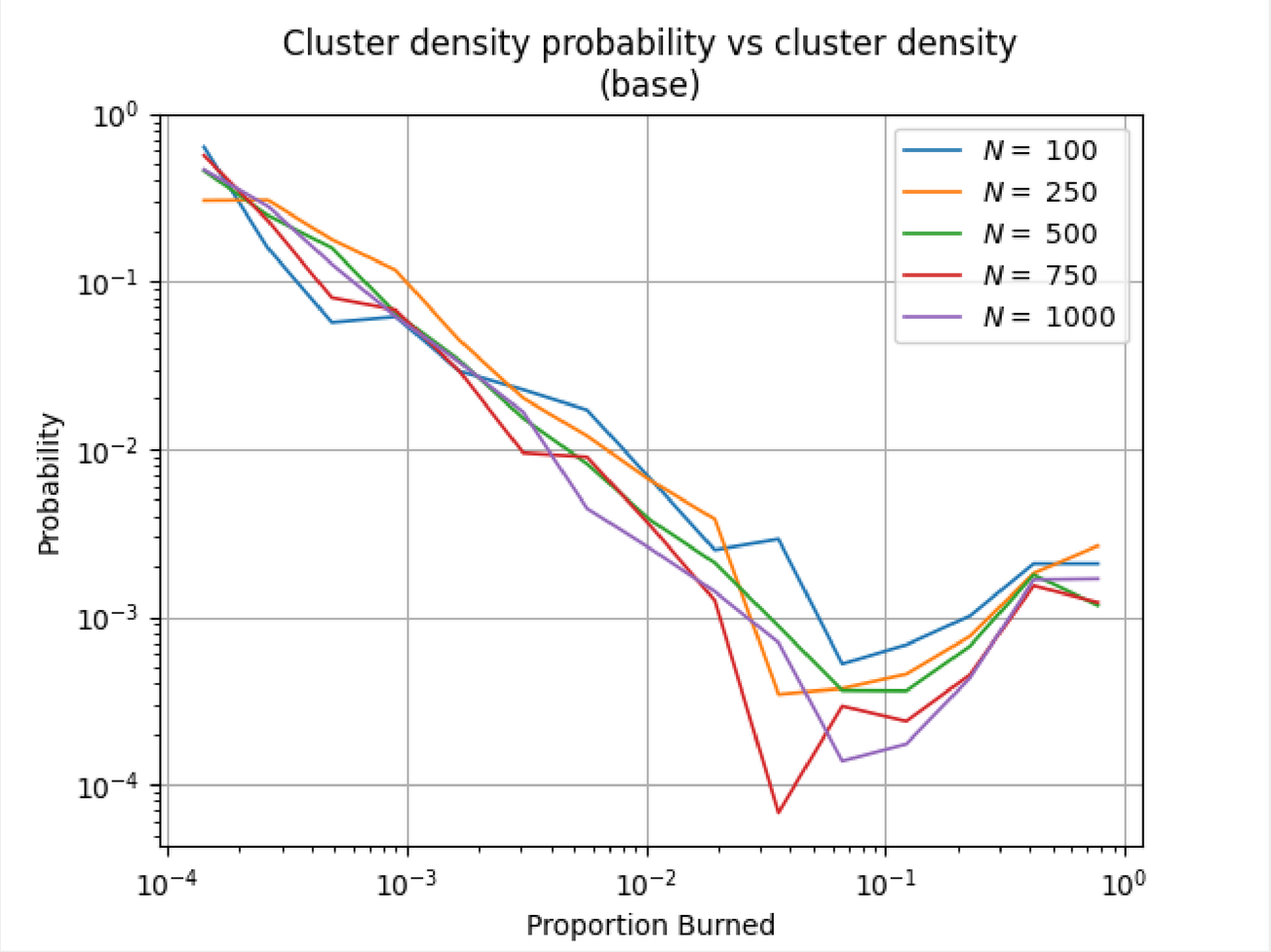
Wind ~ Yes
P ~ 0.5
Plant/Tree ~ 0
ΔTree ~ 1

Critical Density for Plant/Tree Burn Time Dif



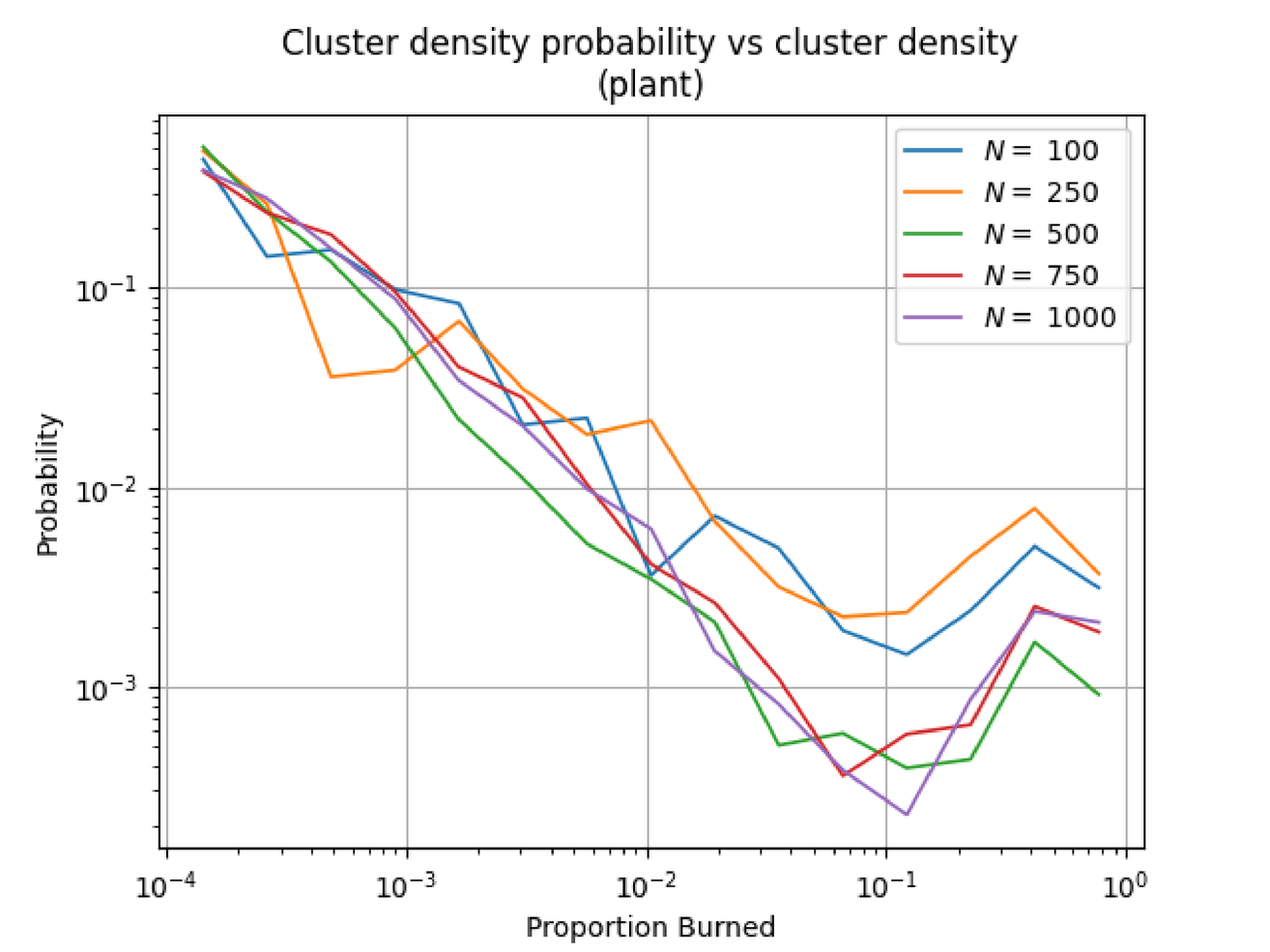
Wind ~ No
P ~ 0.75
Plant/Tree ~ 0.5
ΔTree ~ 3

Data Collapse Base Model



Wind ~ No
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1

Data Collapse Plant Model



Wind ~ No
P ~ 1
Plant/Tree ~ 0
ΔTree ~ 1