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Forest Fire Model and its Self-Organized Criticality

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Outline

1. Motivation

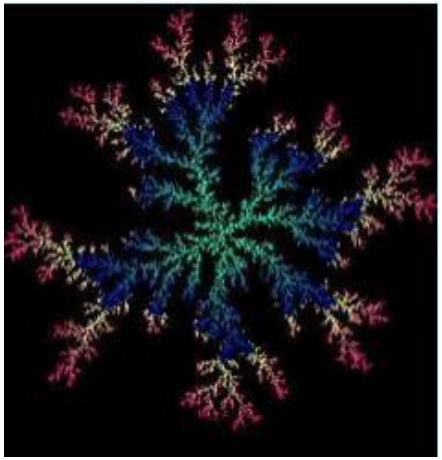
2. Introduction

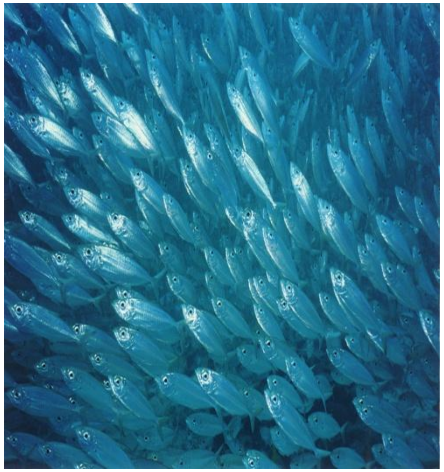
3. Simulation results

4. Conclusion and Outlook

1. Motivation

Self-organized criticality (SOC) can be seen in various systems:





Forest fire is one of the systems

Predict the behavior of a dynamic system

Risk assessment and hazard protection

2. Introduction

2.1 Forest Fire Model (FFM)

Forest:

n*n grid
Empty site-0
Tree-1
Burning tree-2

Rules:

(1) A tree can be ignited by lightening with a probability *f*
(2) A burnt tree will become an empty site
(3) A tree can grow in an empty site with a probability *p*
(4) A burnt tree will cause fire in its neighboring tree with same probability *g*

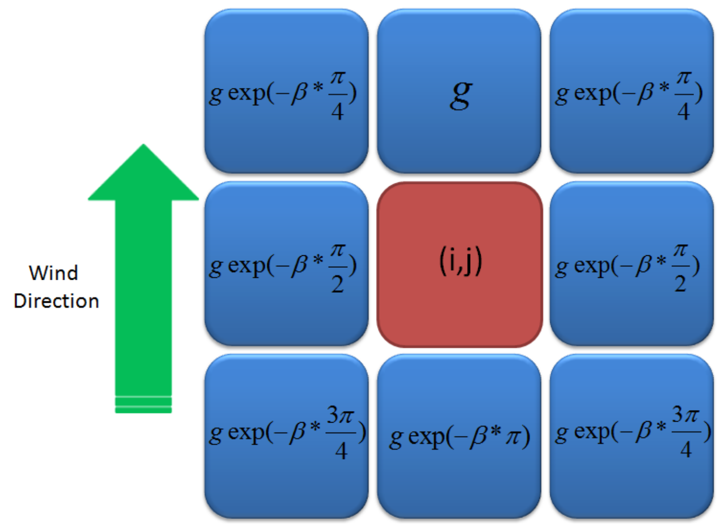
Weather conditions:

Wind:

$$P_w = P_{0w}\exp(-\beta\theta_f)$$

Rain:

$$P_r = P_{0r}\times(1-r)$$



Parameters:

size-n
probLightening-f
probGrow-p
probIgnite-g
density-d
wind-β
rain-r
step-N

2. Introduction

2.2 Self-Organized Criticality (SOC)

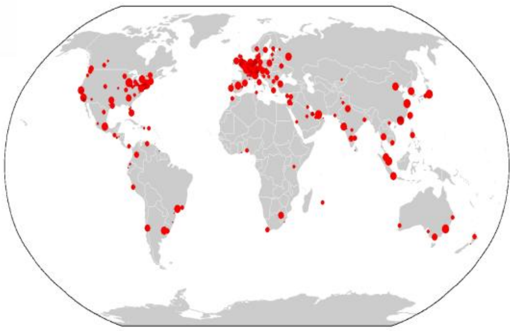
Definition:

A dynamic system can evolve into a **non-equilibrium steady state** **without tuning its parameters**.

Properties:

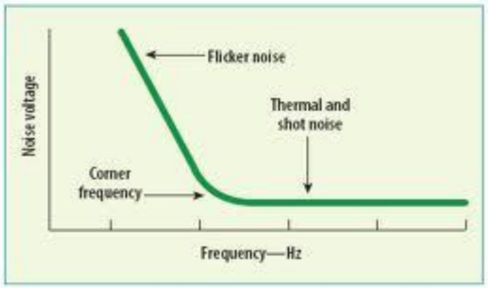
i) Long scale temporal fluctuations

ii) Size-frequency distribution satisfies power-law



iii) Flicker noise

$$\propto 1/f^{\alpha}$$



Flicker noise is low-level semiconductor device noise that increases as a function of inverse carrier frequency, or 1/f.

3. Simulation Results

3.1 Evolution of forest fire

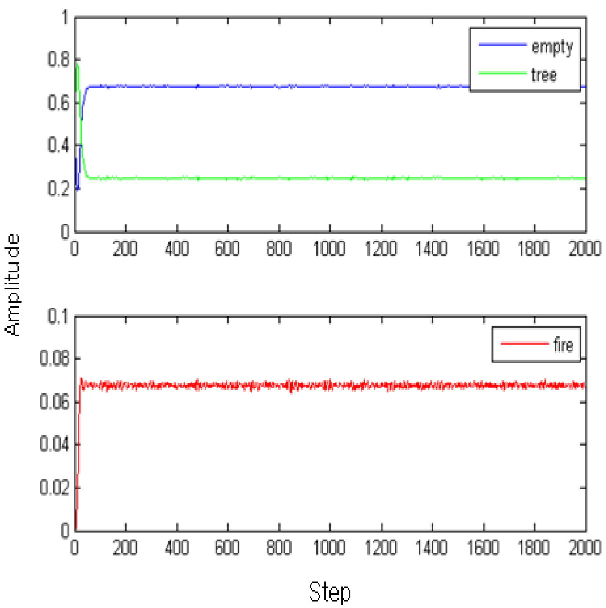
video

3. Simulation Results

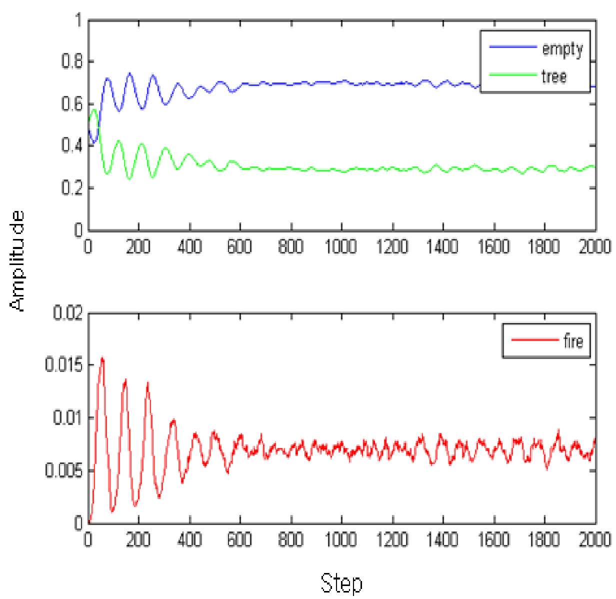
Reminder:
size-n
probLightening-f
probGrow-p
probIgnite-g
density-d
wind-β
rain-r
step-N

3.2 The regime of SOC

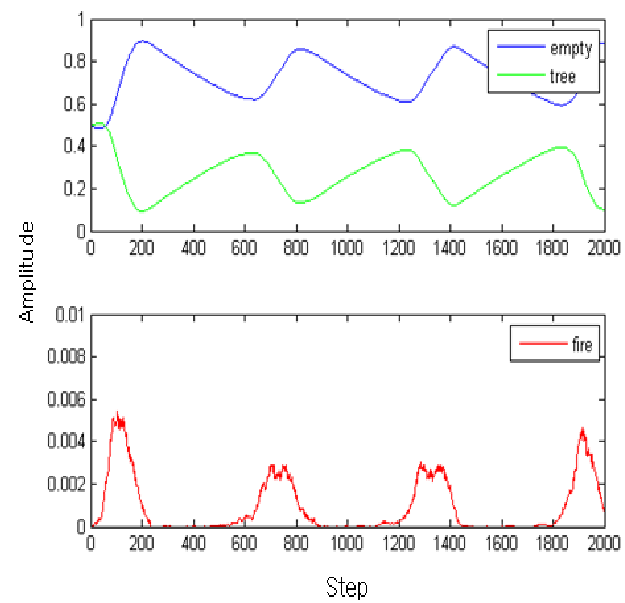
i) Keep $p/f = 10^3$, $n=500$, $d=0.5$, $g=1$, change p



$p=0.05$



$p=10^{-2}$



$p=10^{-3}$

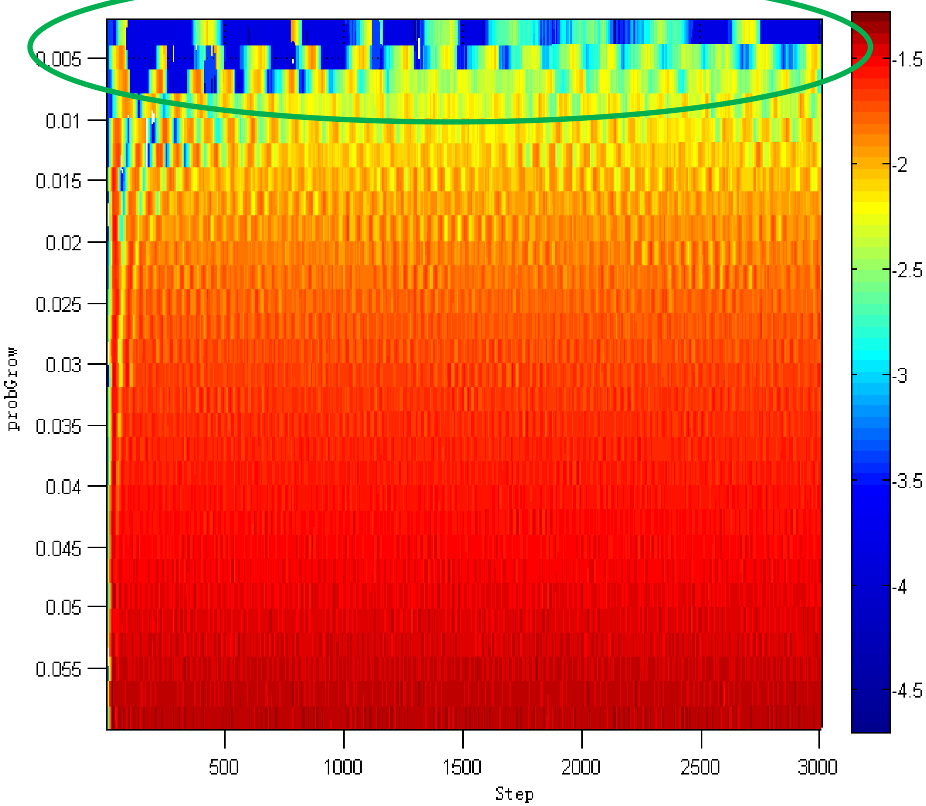
3. Simulation Results

Reminder:
size-n
probLightening-f
probGrow-p
probIgnite-g
density-d
wind-β
rain-r
step-N

3.2 The regime of SOC

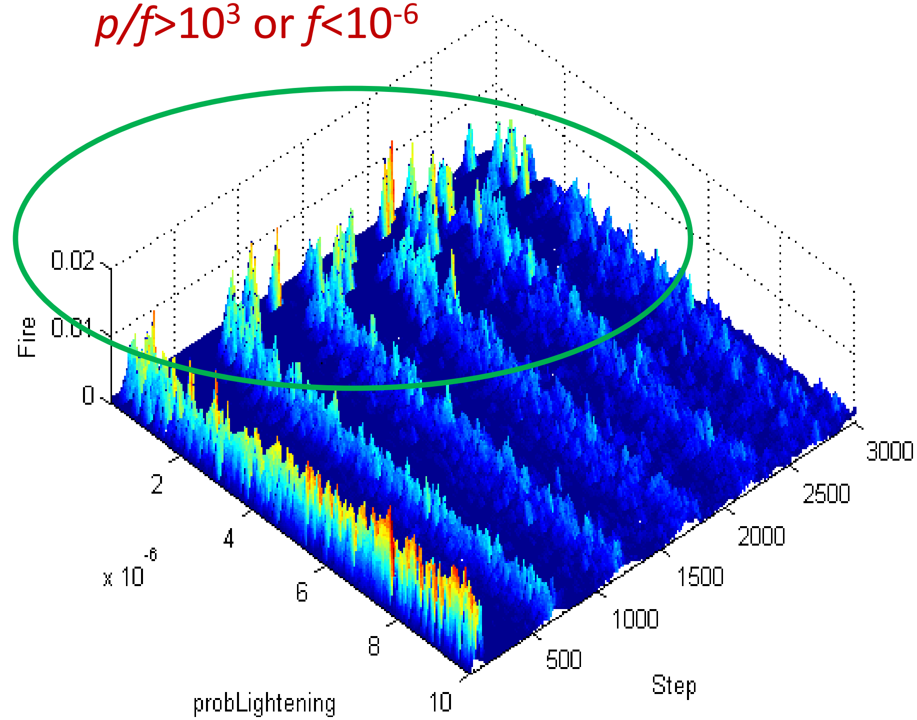
ii) Keep $p/f= 10^3$, n=300, d=0.5, g=1, scan p

p<0.01



iii) Keep p=0.001, n=300, d=0.5, g=1,scan p/f

p/f>10^3 or *f*<10^{-6}



3. Simulation Results

Reminder:
size-n
probLightening-f
probGrow-p
probIgnite-g
density-d
wind-β
rain-r
step-N

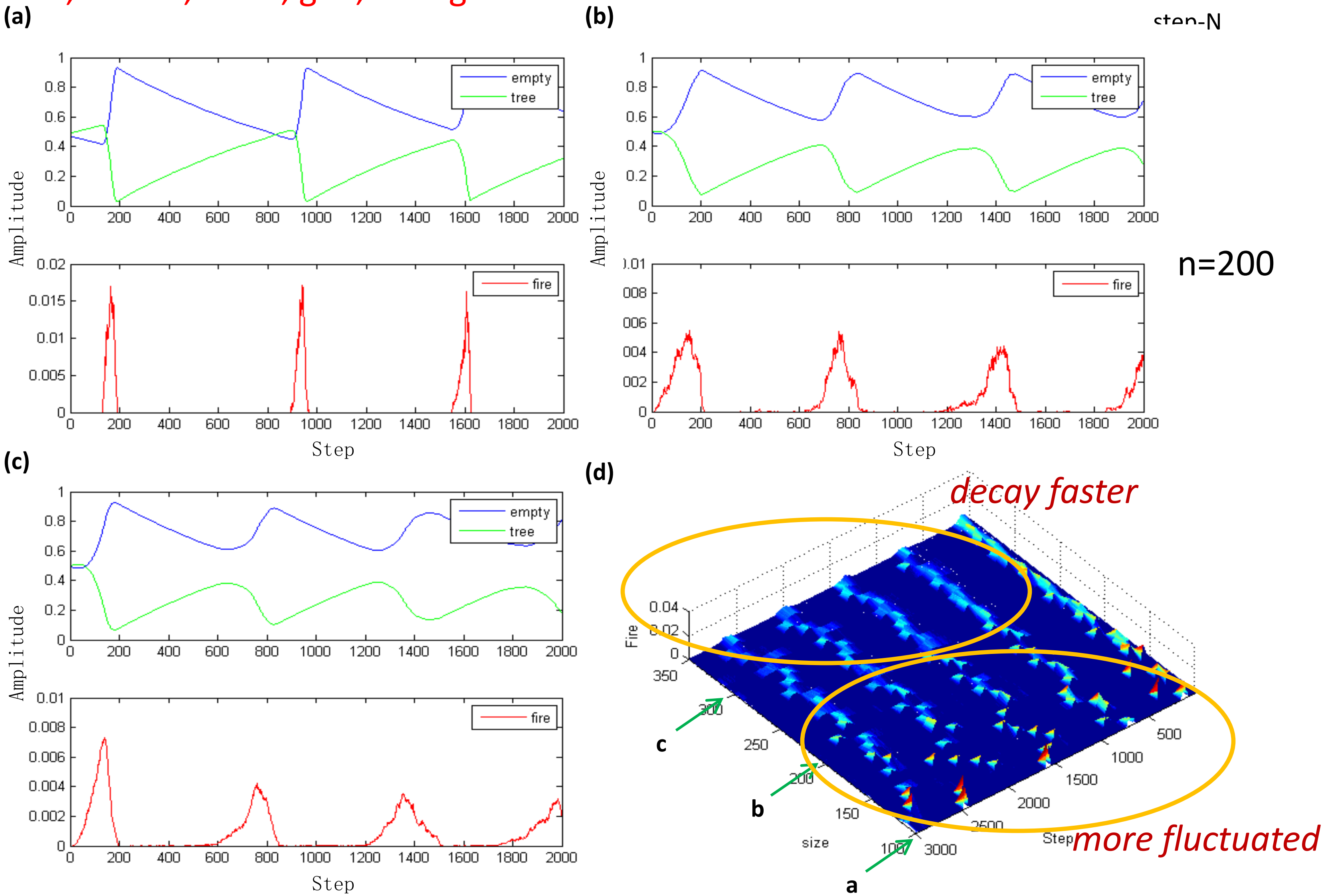
3.3 Effect of forest size

Keep p= 10^{-3}, f= 10^{-6},d=0.5, g=1, change n

n=100

n=200

n=300



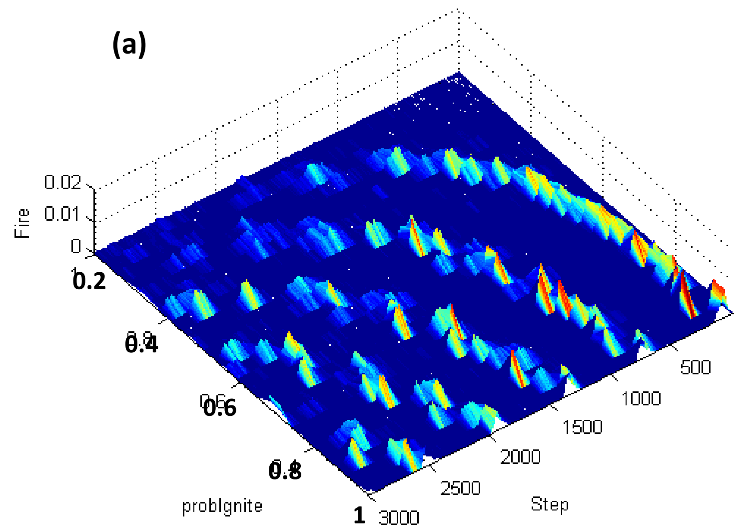
3. Simulation Results

Reminder:
size-n
probLightening-f
probGrow-p
probIgnite-g
density-d
wind-β
rain-r
step-N

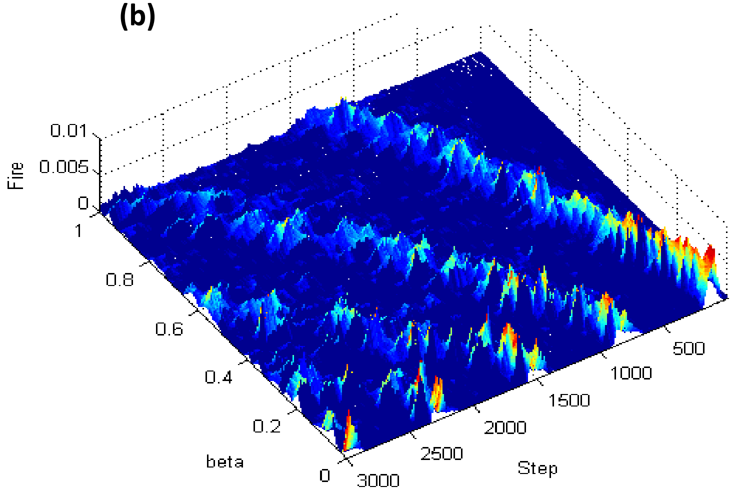
3.4 Scan other parameters

Keep p= 10^{-3}, f= 10^{-6},d=0.5, n=300, scan g, β, r

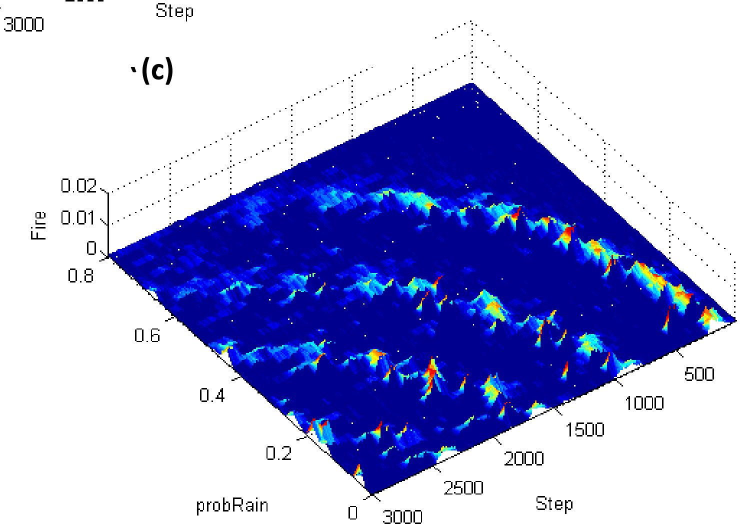
(a)



(b)



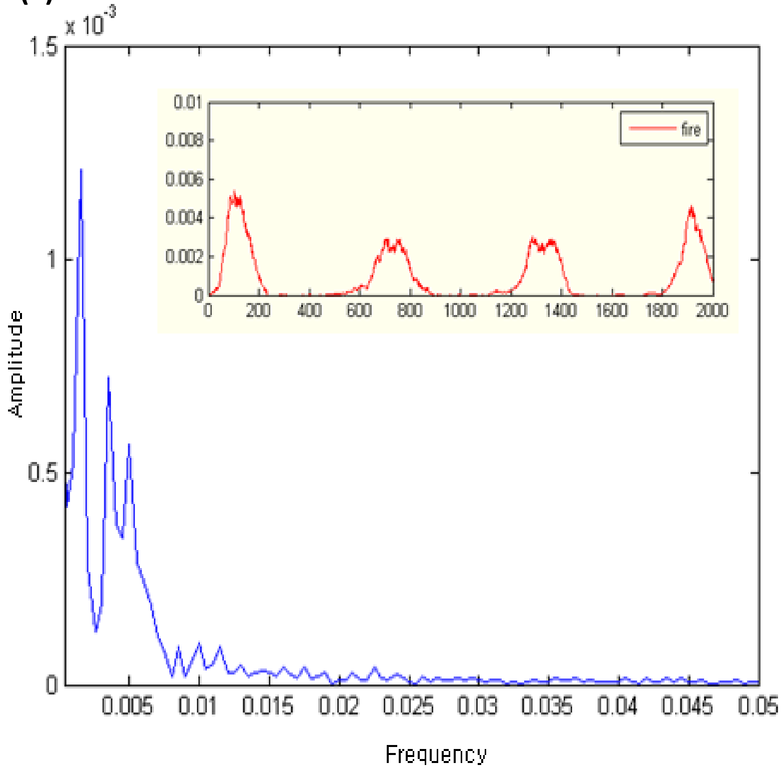
(c)



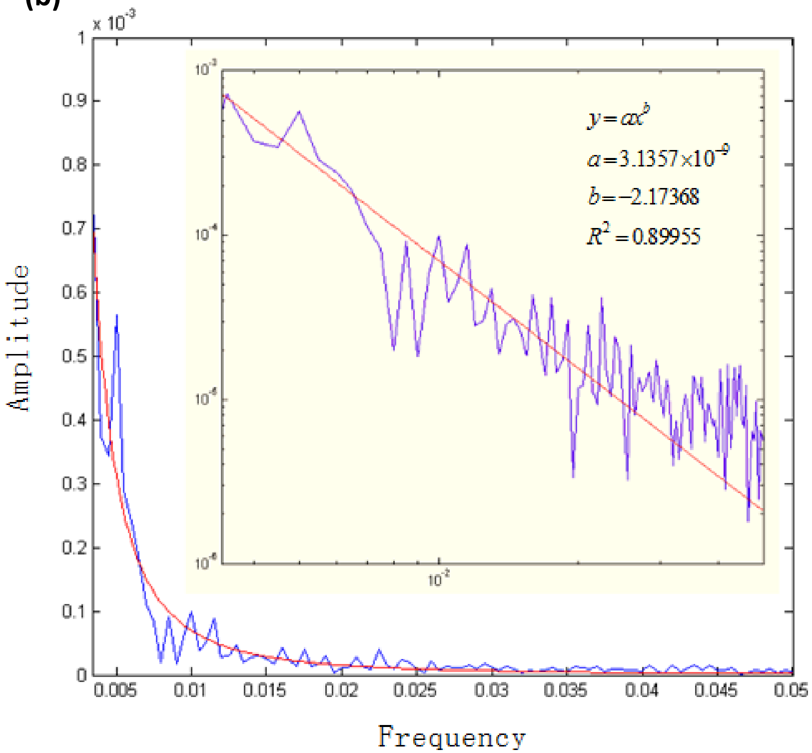
3. Simulation Results

3.5 Flicker noise

(a)



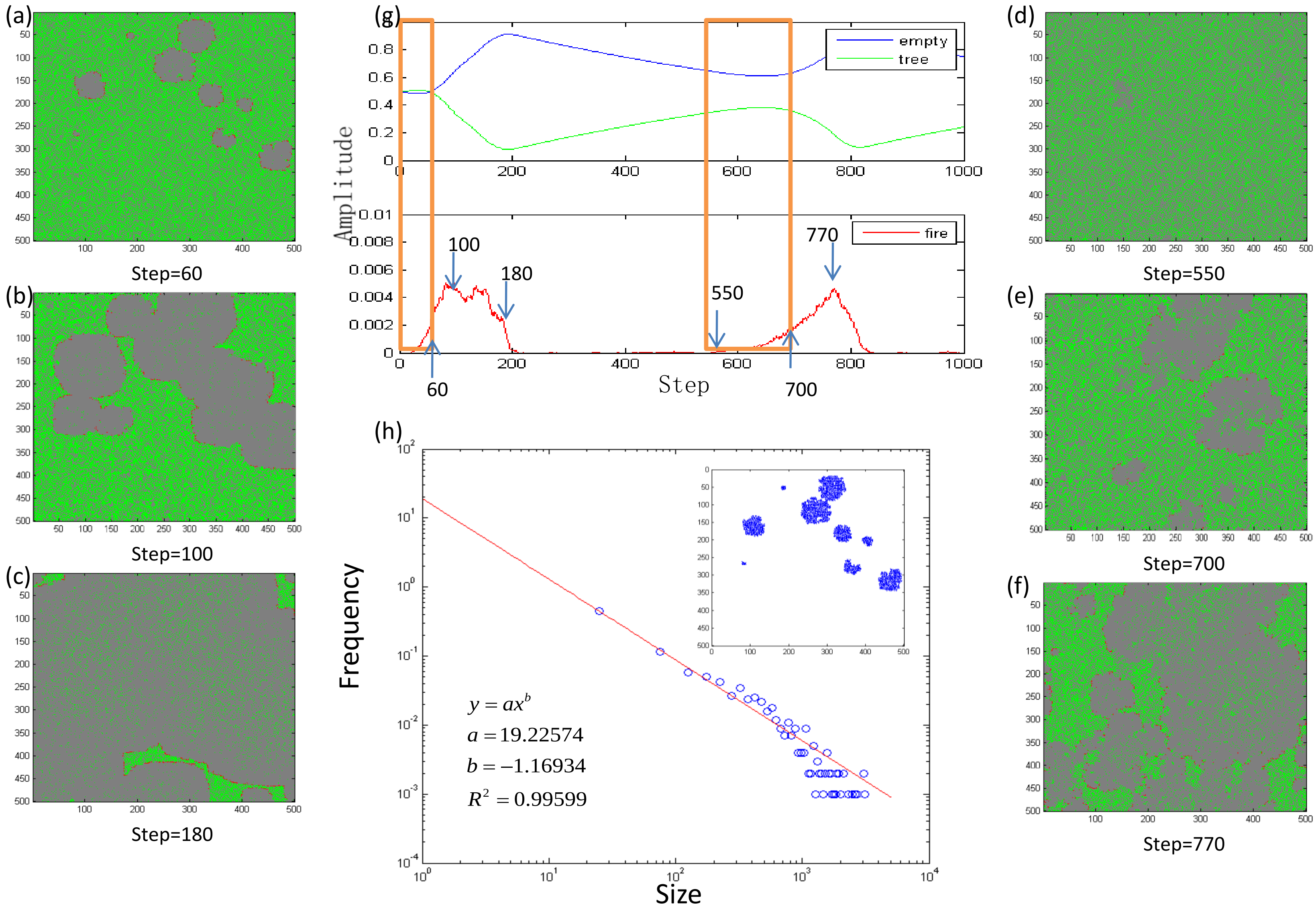
(b)



Noise spectrum ~ f^{-2}

3. Simulation Results

3.6 Size-frequency distribution



4. Conclusion & Outlook

In this project:

1) We build a FFM based on CA
2) We scan different parameters to characterize our FFM
3) We observe the long scale temporal fluctuations of SOC states
4) We observe the ‘flicker noise’ in the noise spectrum
5) We show size-frequency distribution of fire clusters in our FFM satisfies the power-law

More things in the future:

Study larger forest within longer time scale
Consider more factors: landscape, species of tree ……
Scan power spectrum with different parameters
Understand the physical background behind the ‘flicker noise’ and the power-law distribution

Thanks for listening!