Geospatial Analytics in Human-Environment Research: Experiences and Opportunities

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Extremely important

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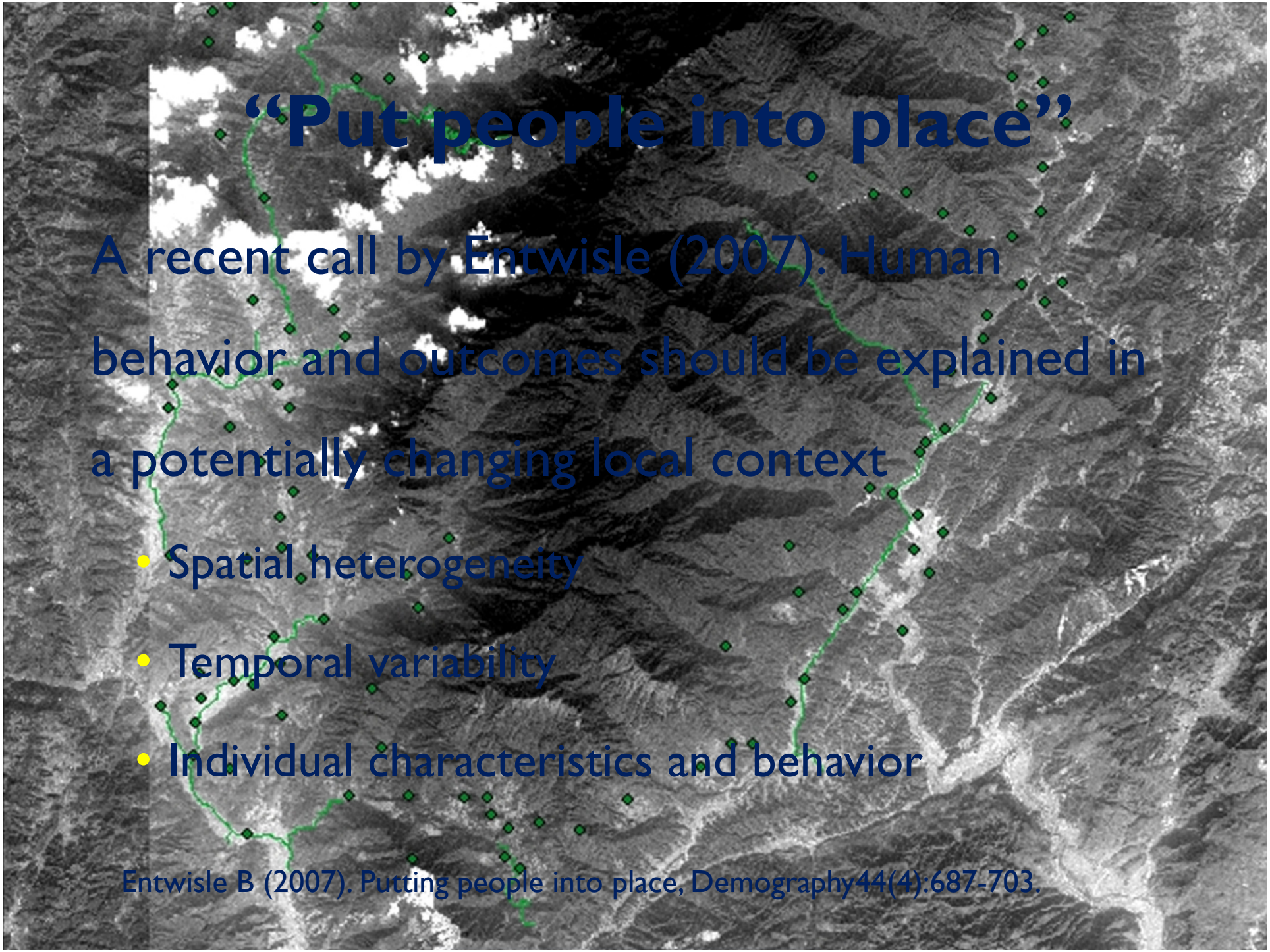
Human-environment science

- Traditional approach
  - Unidirectional
  - Disciplinary
  - Top-down approach
- Coupled human and natural systems (CHANS) approach (e.g., Liu et al. 2007)
  - Feedback
  - Time lags
  - Heterogeneity
  - Nonlinear relationships, etc.



"Put people into place"

A recent call by Entwisle (2007): Human behavior and outcomes should be explained in a potentially changing local context

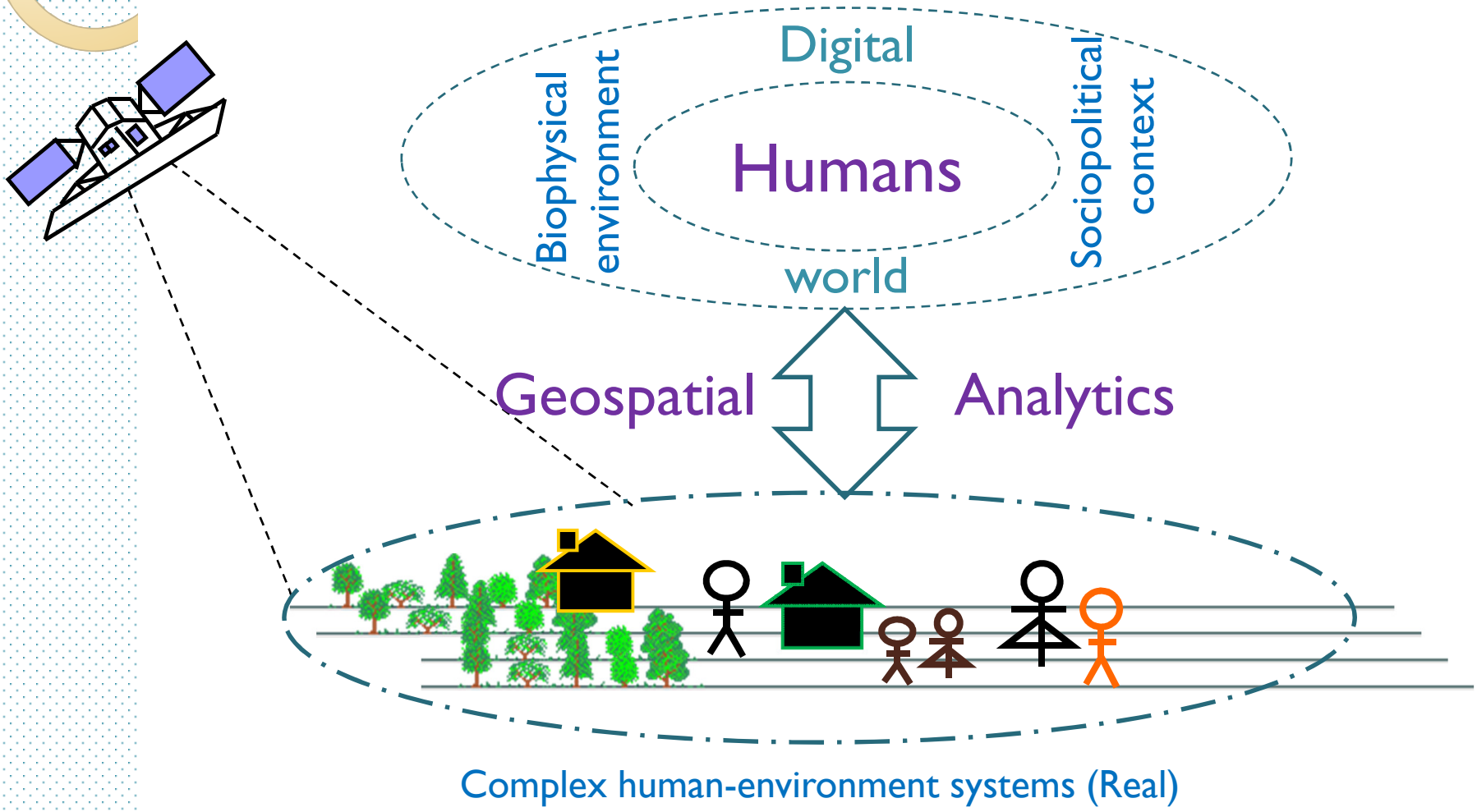
- Spatial heterogeneity
- Temporal variability
- Individual characteristics and behavior

Entwisle B (2007). Putting people into place, Demography44(4):687-703.

Payments for Ecosystem Services (PES) project

Impacts of Ecosystem Service Payments in Coupled Natural and Human Systems
(DEB-1212183). L. An, S. Aitken, D. Stow, R. Lewision, X. Chen. $1.30 million, 2012-2016/2017

Geospatial Analytics for Human Environment Research



Payments for Ecosystem Services (PES)

- Incentives paid to users of natural resources
  - Protect the **environment**: ecosystem structure, function, and services
  - Protect the **people**: economic incentives help maintain quality of life and well-being
- Lack of sustainability
  - Resource users return to pre-PES behavior
  - Effective for a short time (The curse of no "permanence")

Grain-to-green program (GTGP)

(PES in China)

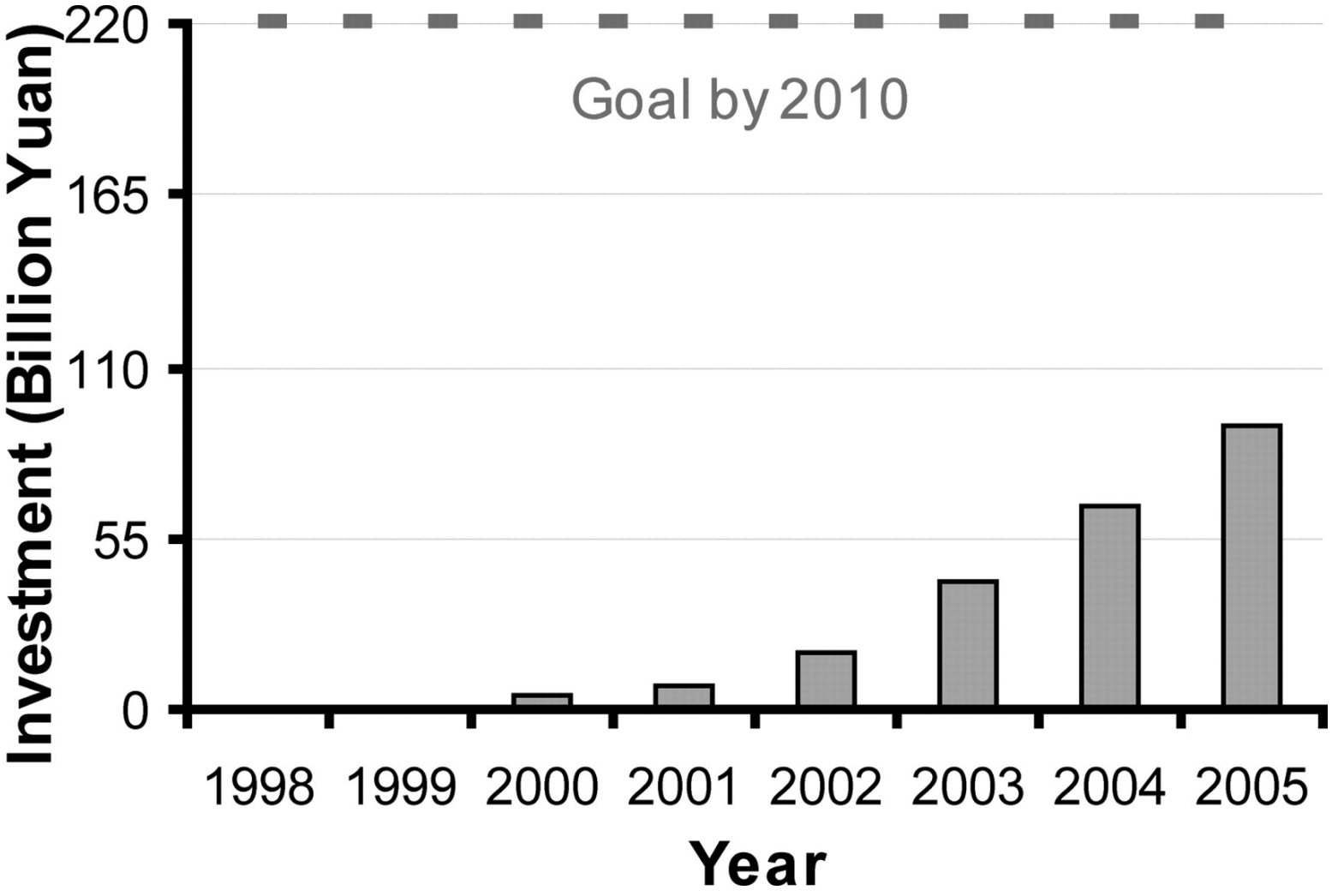
- Pay individual households for planting trees on sloped land:
  - Grain, cash, and seedlings
  - Technical support
- GTGP detail varies in:
  - Payment amount
  - Payment span
  - Steepness standard

National Forest Conservation Program (NFCP)

A program that conserves natural forests through logging bans and afforestation with incentives to forest enterprises (Zhang et al. 2000; Liu et al. 2008)

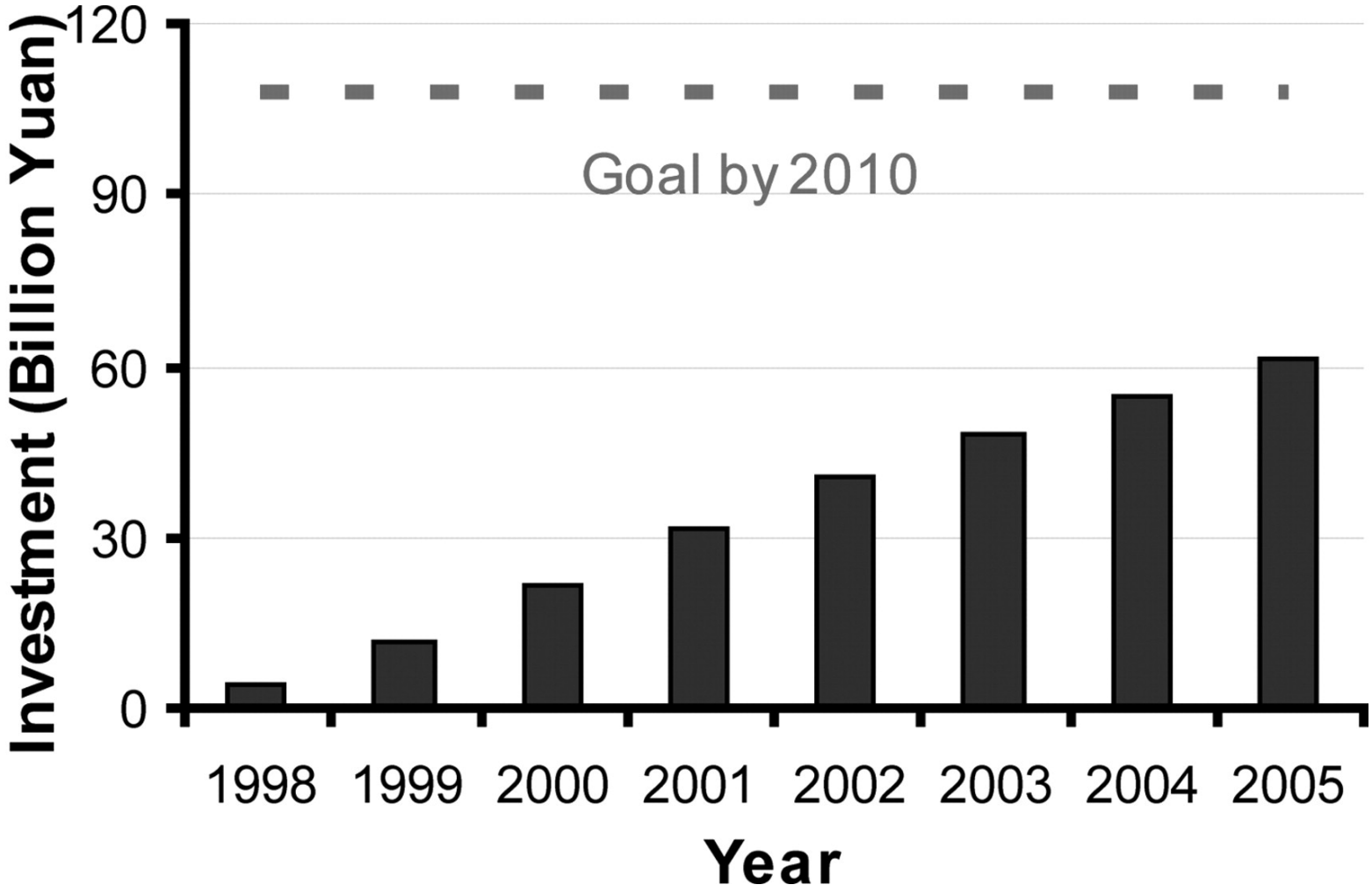
1. Zhang et al. (2000). China's forest policy for the 21st century . Science 288: 2135-2136.
2. Liu et al. (2008). Ecological and socioeconomic effects of China's policies for ecosystem services. PNAS 105: 9477-9482

Cumulative amount of investment in the GTGP from 1999 to 2005.



Jianguo Liu et al. PNAS 2008;105:9477-9482

Cumulative amount of investment in NFCP (1998–2005).



Jianguo Liu et al. PNAS 2008;105:9477-9482

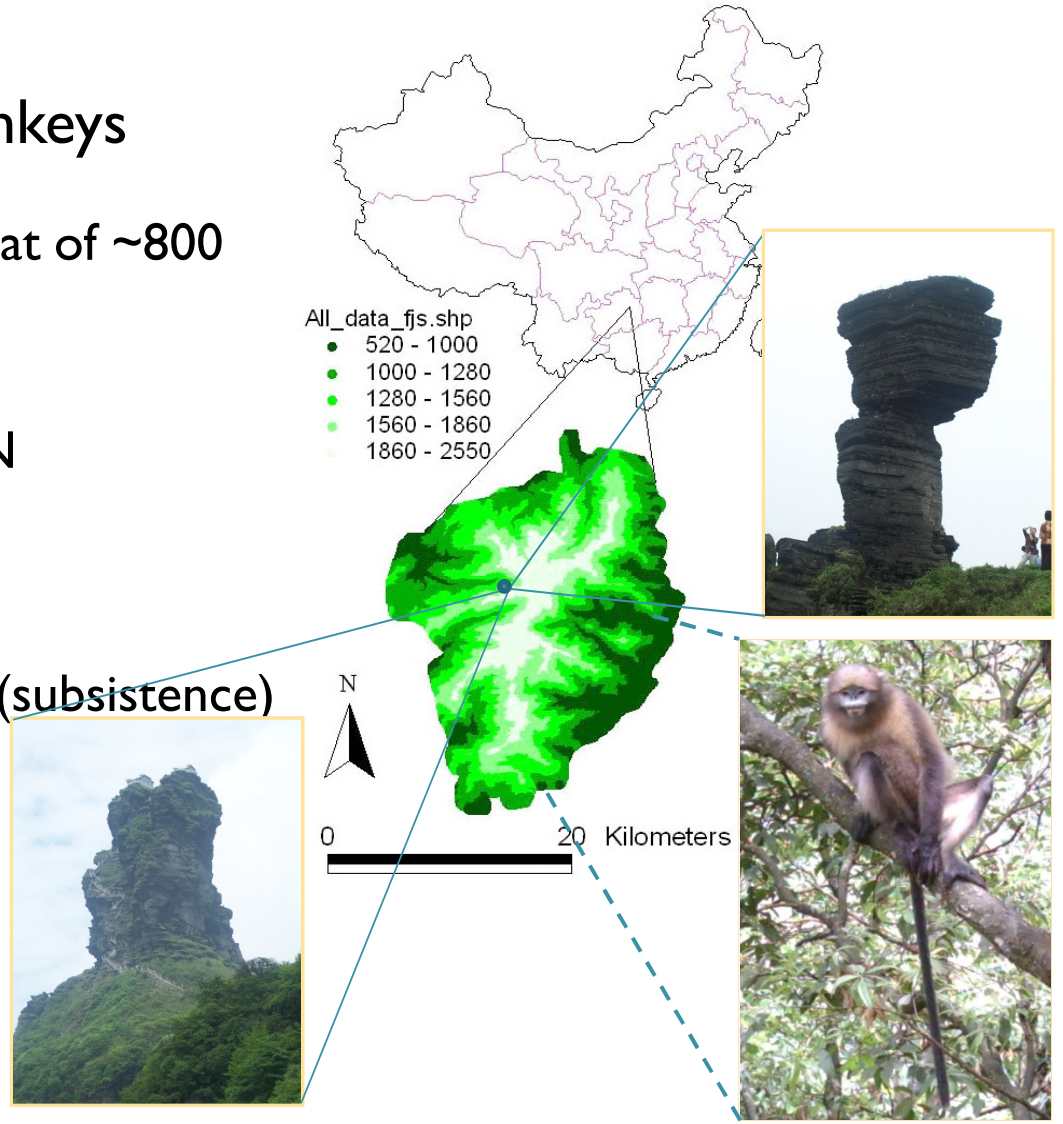

GTGP & NFCP
GTGP only
No GTGP or NFCP
Heilongjiang
Jilin
Inner Mongolia
Liaoning
Beijing
Xinjiang
Gansu
Yellow River
Tianjin
Hebei
Qinghai
Ningxia
Shanxi
Shandong
Shaanxi
Henan
Jiangsu
Tibet
Anhui
Sichuan
Chongqing
Hubei
Zhejiang
Jiangxi
Hunan
Yangtze River
Fujian
Guizhou
Taiwan
Yunnan
Guangxi
Guangdong
Hainan

Research goals

- What changes have taken place since PES implementation?
- What mechanisms stand behind such changes?
- (How) Can we envision temporal trajectories of PES systems in a geospatially explicit way?

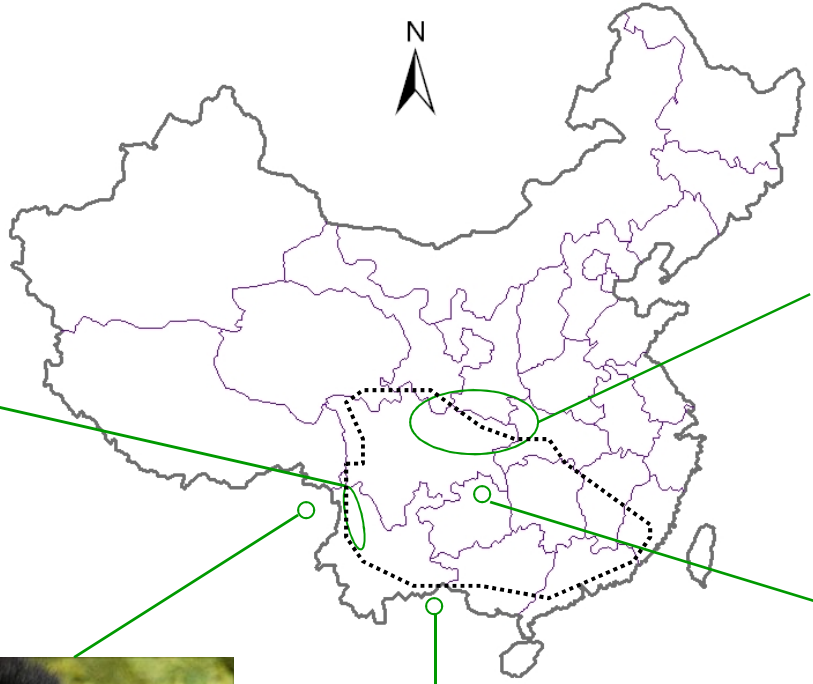
Fanjingshan National Nature Reserve

- Guizhou Golden monkeys
  - The only and last habitat of ~800 animals
  - "Endangered" by IUCN
- Local communities
  - 11,000 local residents (subsistence)
  - Over 70,000 tourists
  - PES in operation

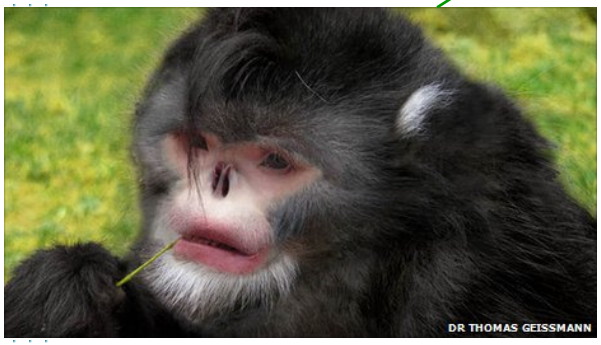


Rhinopithecus

***R. bieti* 1,500**
(Yunan)

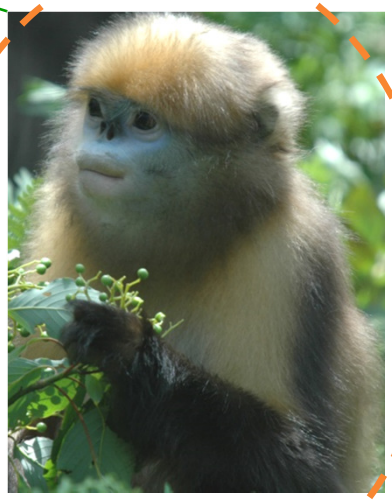


R. roxellana
15,000 (Sichuan)



R. Strykeri
<300 (Myanmar)

R. avunculus
<200 (Vietnam)



R. brelichi
800 (Guizhou)

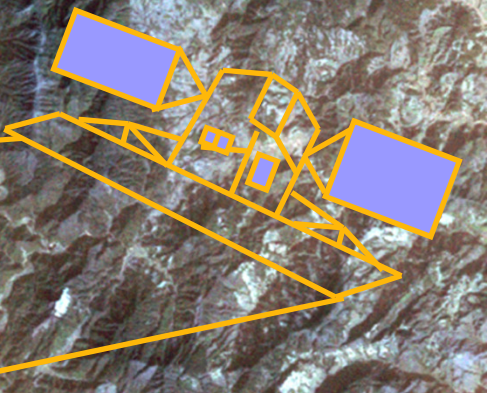
Photo courtesy: Chia Tan, Xiaoping Lei, www.ibn-tv.com

Forest changes due to PES?

Envision

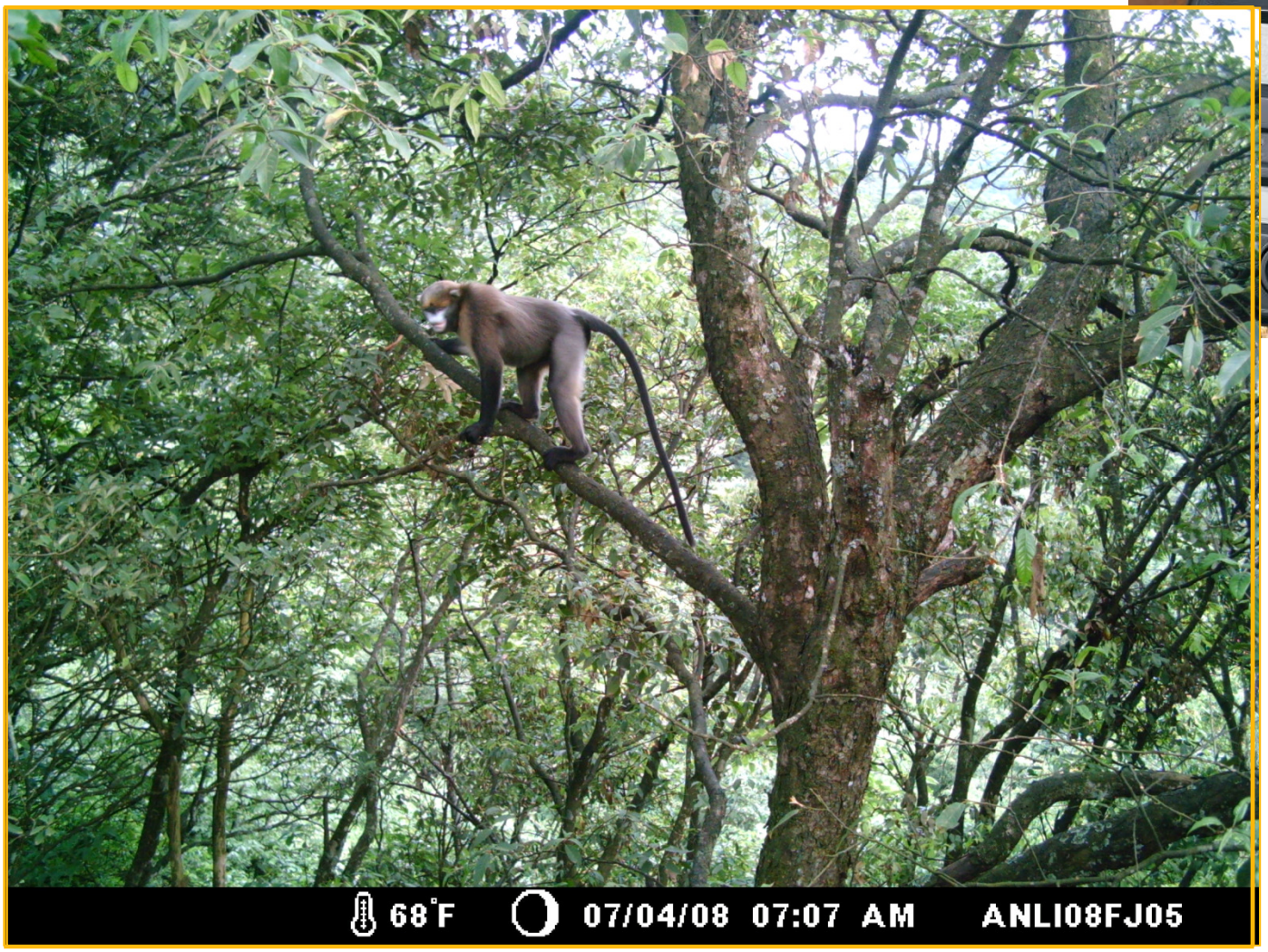
mechanisms

Changes



- Canopy fractional cover
- Vegetation classes

Changes in monkey occupancy with PES?



Envision

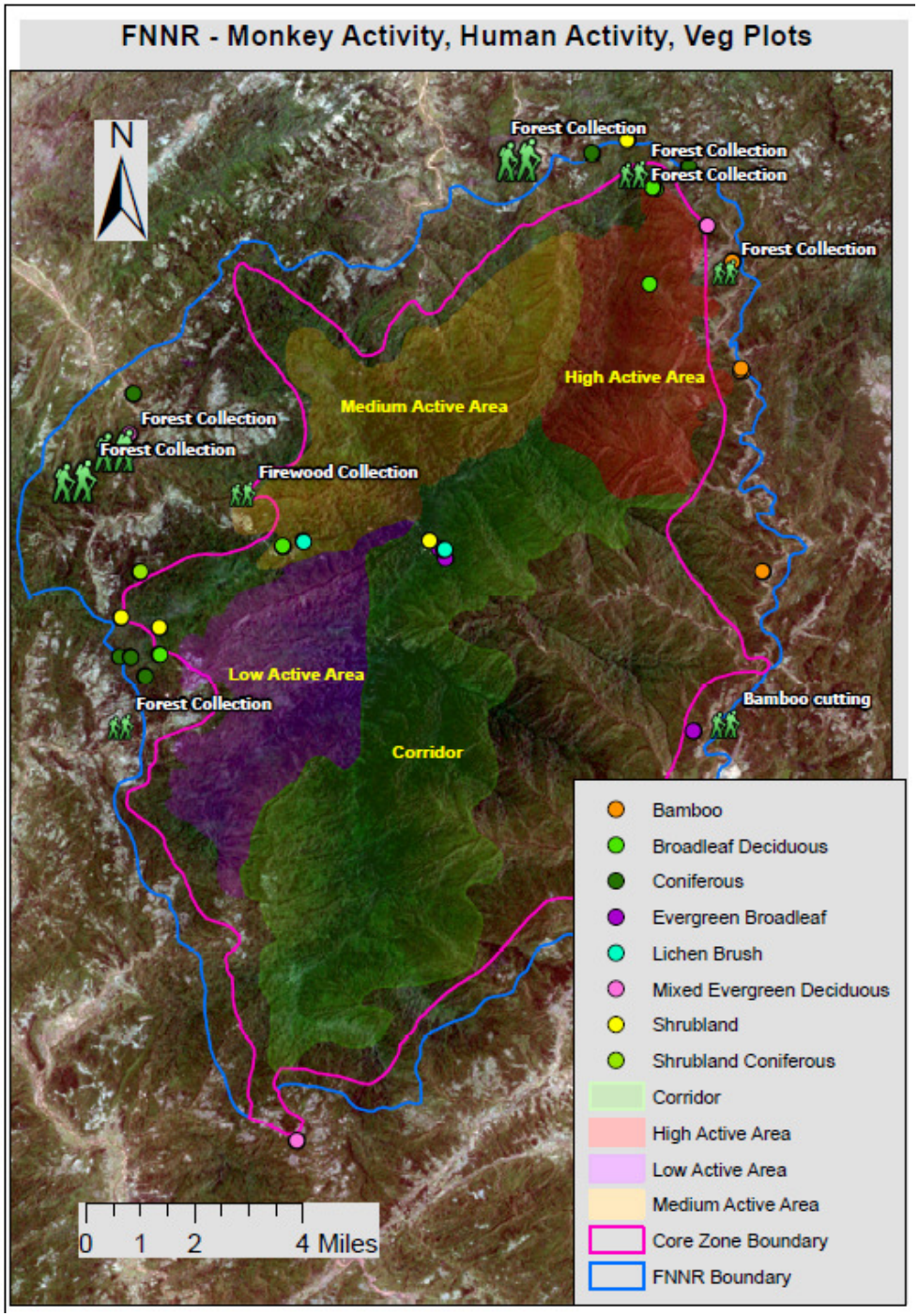
mechanisms

Changes

Changes in human activity?

Changes mechanisms Envision

Participatory mapping



Envision

mechanisms

Changes

Changes in demography, livelihood, and land use

- Demography (HH location too)
- Local off-farm business
- Resource extraction
- Agriculture
- Migration & place attachment
- Household living conditions
- GTGP & NFCP info
- Social norm

Human decision making

- Discrete choice modeling
  - Probability (enroll) =

    f (GTGP features, social norm, HH/Personal features, Land features)
  - A Probit multilevel (household and village) model

"By accident" we found…

PES programs are weakening / canceling out each other!!!

Higher NFCP pay,

lower GTGP enrollment

- The odds of GTGP enrollment will decrease by 17% with additional 1000 Yuan of NFCP payment

More NFCP land,

lower GTGP enrollment

- The odds of GTGP enrollment will decrease by 1% with additional mu of NFCP

More frequent NFCP patrols, lower GTGP enrollment

- The odds of enrollment will decrease by 5% with additional patrol-trip

The closer GTGP parcels, the more likely to support NFCP

- The odds of supportiveness will decrease by 5% with an additional minute of travel

Envision

mechanisms

Changes

Geospatial analytics chimes in

- A spatially explicit agent-based model (ABM)
  - DEM and RS enable spatial representation
  - ABM enables temporal representation
  - Individual (people and households) decisions and actions
  - Python ABM (Aim to write a book)
- Spatial filtering in regression analysis
  - Eigenvector spatial filtering (ESF)

Opportunities

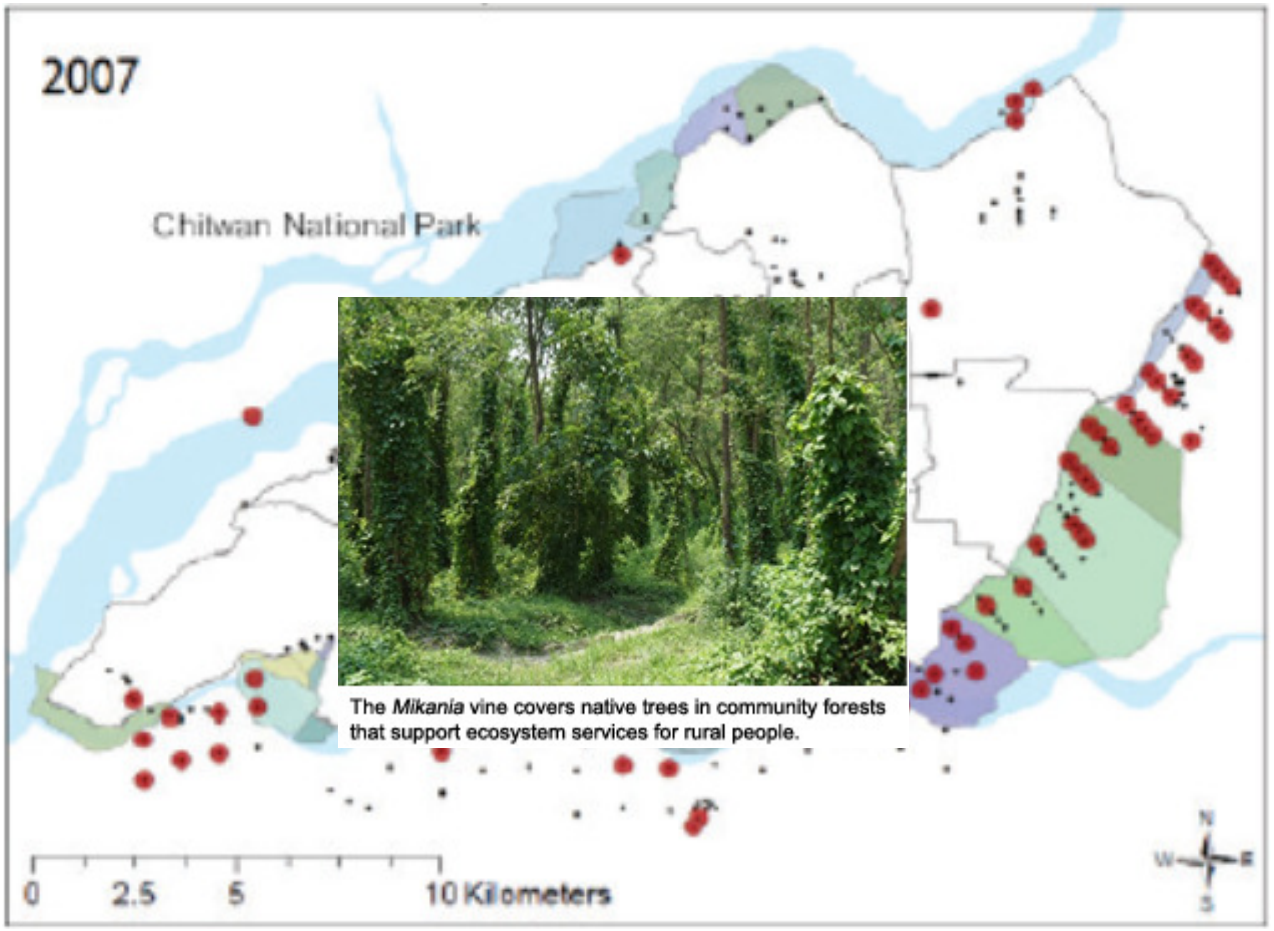
- Tourism-induced livelihood change
- Leisure behavior and physical/mental health
- Emerging issues:
  - "Farmers' joy" tourism is popular in FNNR
  - Adventure tourists' need
  - Migration induced youth exodus vs. local off-farm jobs
  - Natural resources and cultural heritage: loss and degradation


Golf course
Image © 2016 CNES / Astrium
© 2016 Cnes/Spot Image
Image © 2016 DigitalGlobe
10.1 km


Huangjiaba
Golf course
Kaima
Image © 2016 CNES / Astrium
© 2016 Cnes/Spot Image
475 m

Other geospatial analytics about human-environment research

Human responses to Mikania



PIRE collaborative research and training in social context, population processes, and environmental change (OISE-0729709). W. Axinn, J. Liu, L. An, & S. Yabiku, L. Pearce. $2.5 million, 2007-2012/2013

Feedbacks between human community dynamics and socio-ecological vulnerability in a biodiversity hotspot (BCS-1211498). S. Yabiku, Li. An, D. Ghimire, S. Hall, A.M. York, $1.45 million, 2012-2016/2017

Surprisingly…

Geospatial analytics could offer unique insights about human dimensions in natural or built environments!

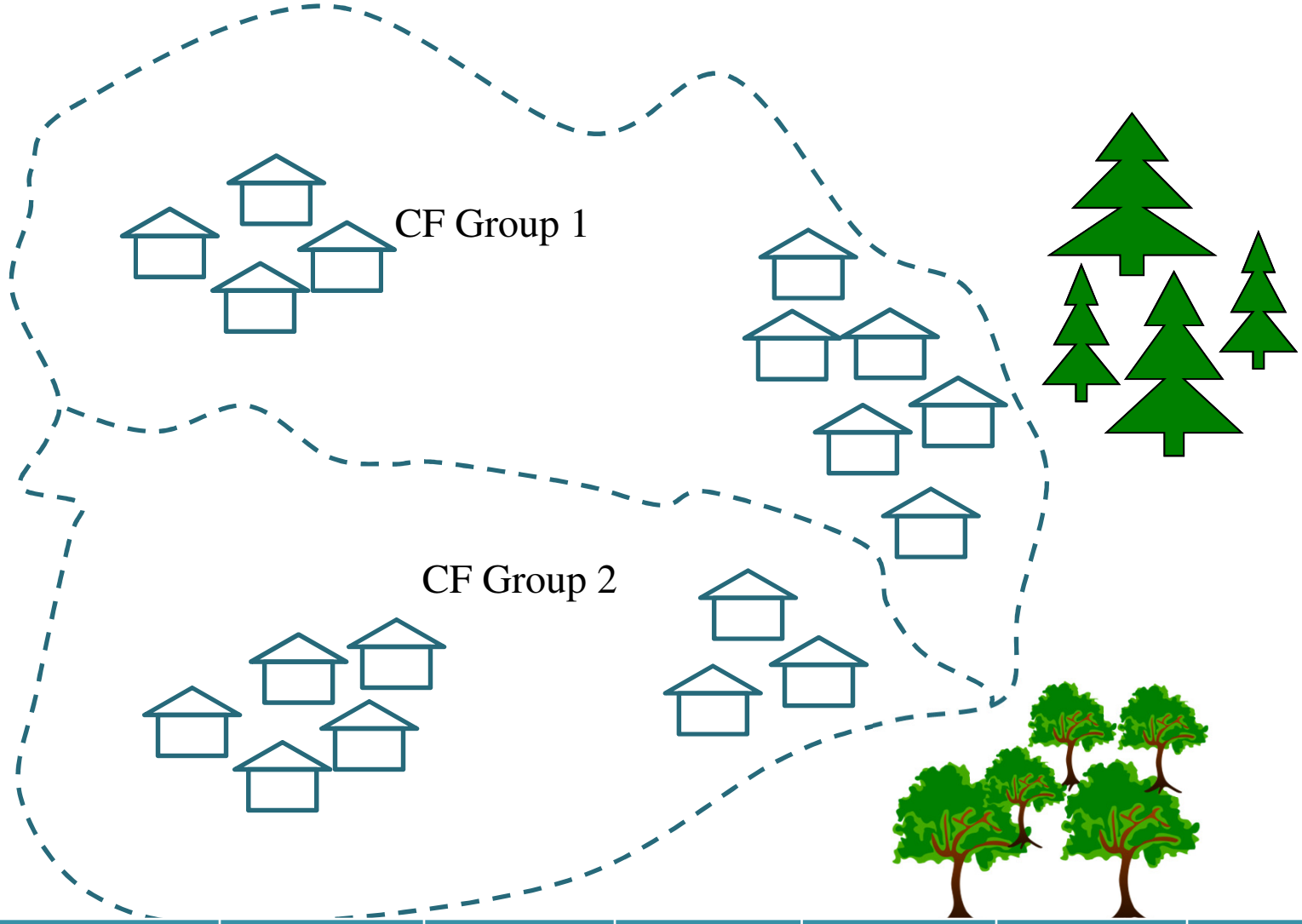
Capturing spatial diffusion

(Eigenvector spatial filtering)

To predict household Mikania control willingness:

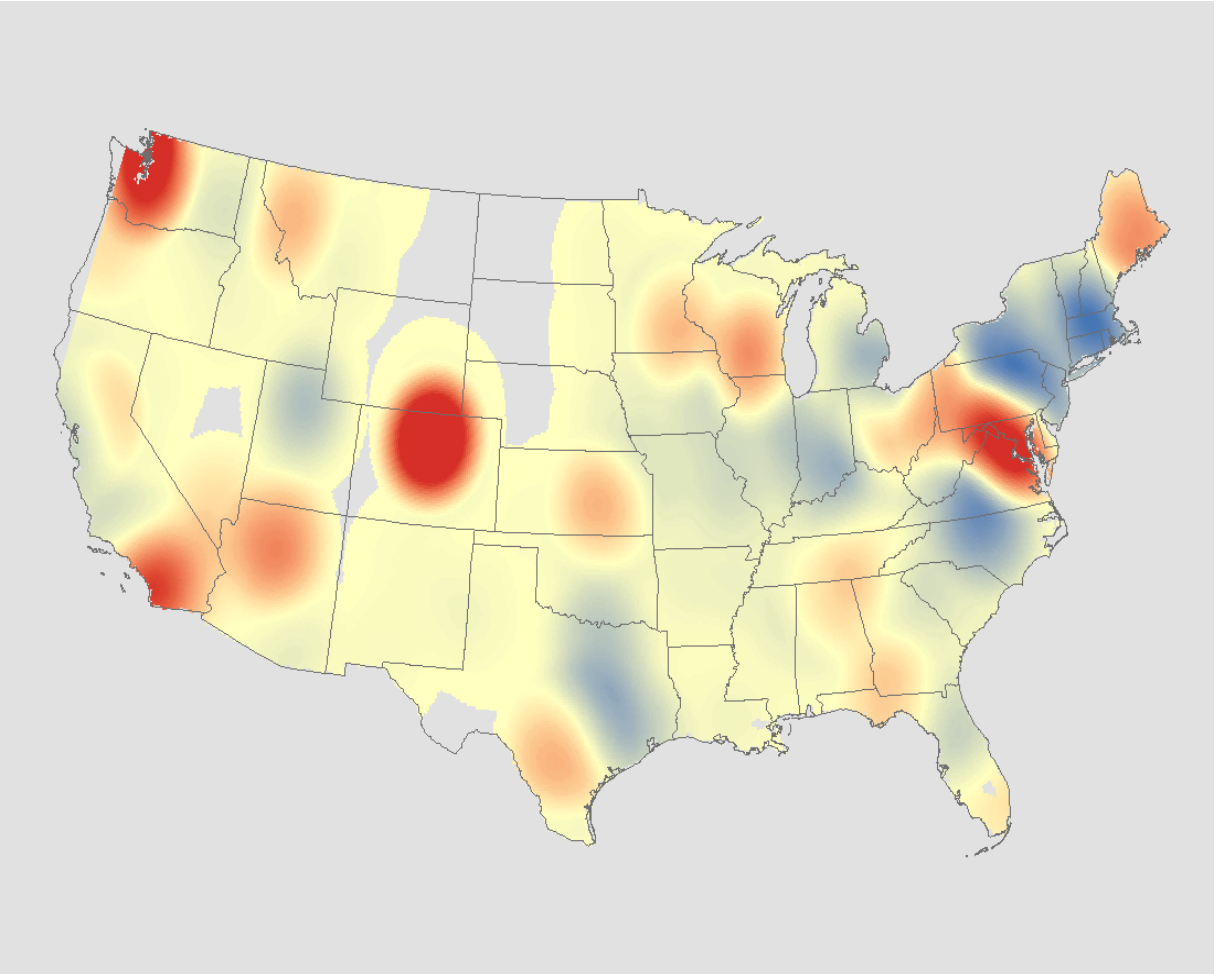
Model	No filtering	NBH 10	NBH 20	NBH 30	NBH 40	NBH 50
Level 1 (Household) predictors						
Household distance to CF	-0.1443	**-0.3756****	-0.1522	-0.2400	**-0.3104****	-0.2416
Level 2 (Community forest group) predictors						
CF income	-0.0572	0.1454	-0.007164	**-0.4018*****	**-0.372*****	**-0.3969*****
CF perceived threat	**-0.5974***	**-0.8761****	**-0.7266***	0.3549	0.1596	0.0084

p<0.0000 ***, p<0.01 **, p<0.05*; N = 1041 households, 21 Community Forest Groups



Model	No filtering	NBH 10	NBH 20	NBH 30	NBH 40	NBH 50
CF perceived threat	**-0.5974***	**-0.8761****	**-0.7266***	0.3549	0.1596	0.0084

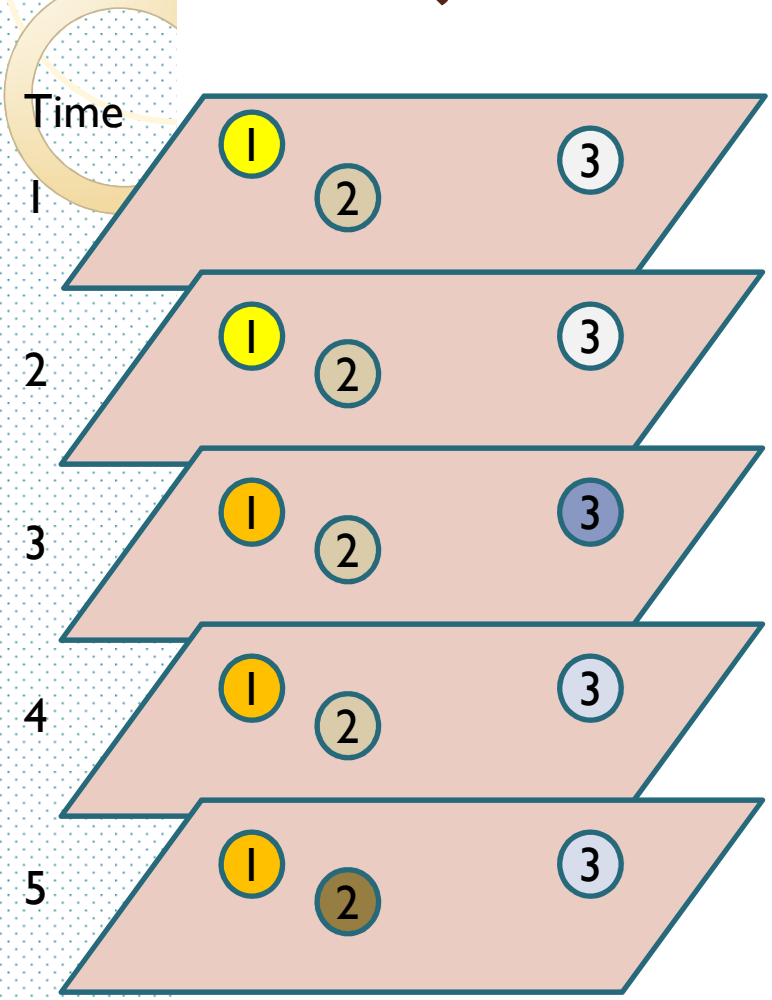
Popularity of "climate change"
(Data from Yahoo Search)



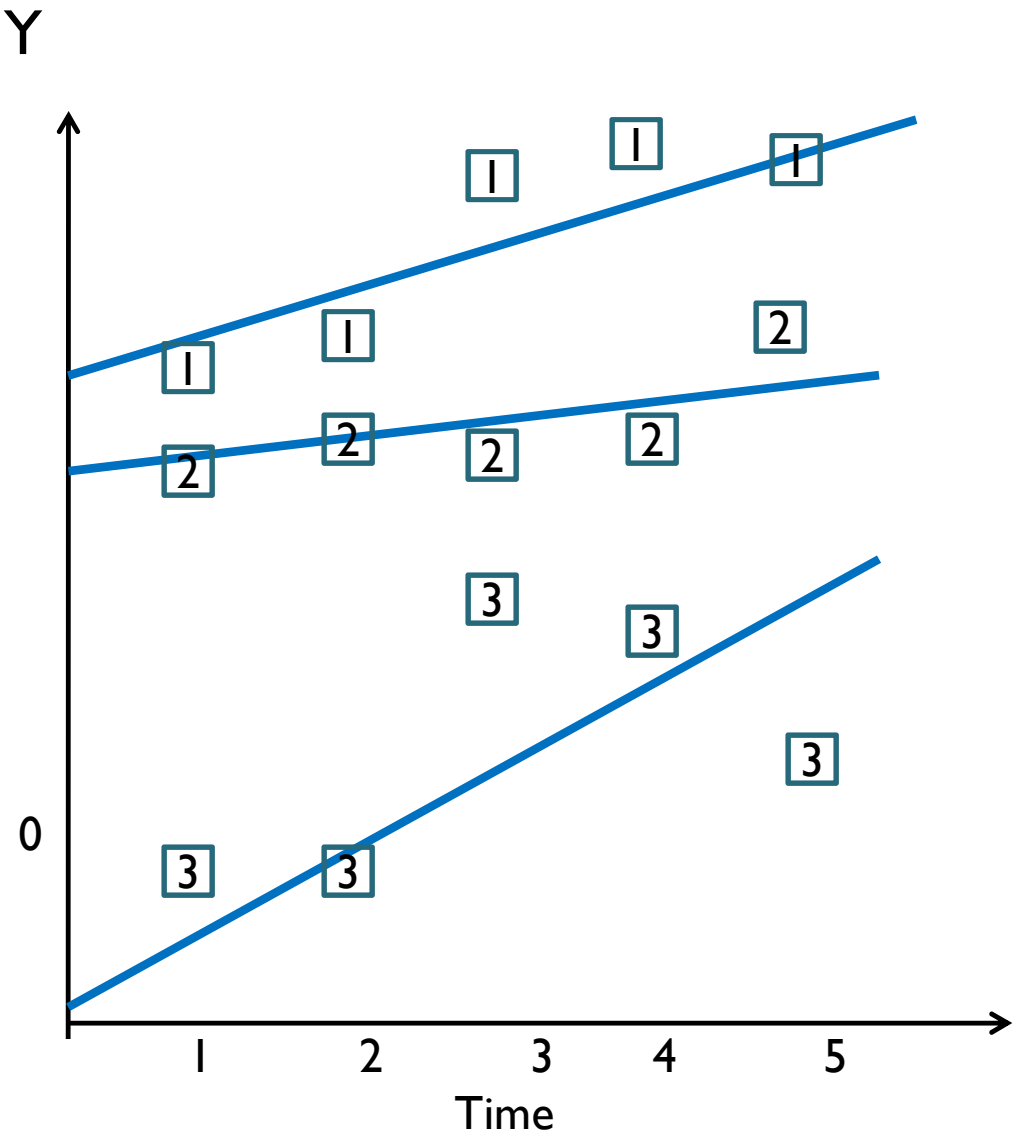
Mapping Cyberspace to Real-Space, NSF CDI Project, 2010-2014, $1.3 million M. Tsou (PI), D. Gupta, J. M. Gawron, B. Spitzberg, L. An

How do we represent and model temporal variability without ignoring spatial variability?

Trajectories:



The numbers are unique IDs of spatial units



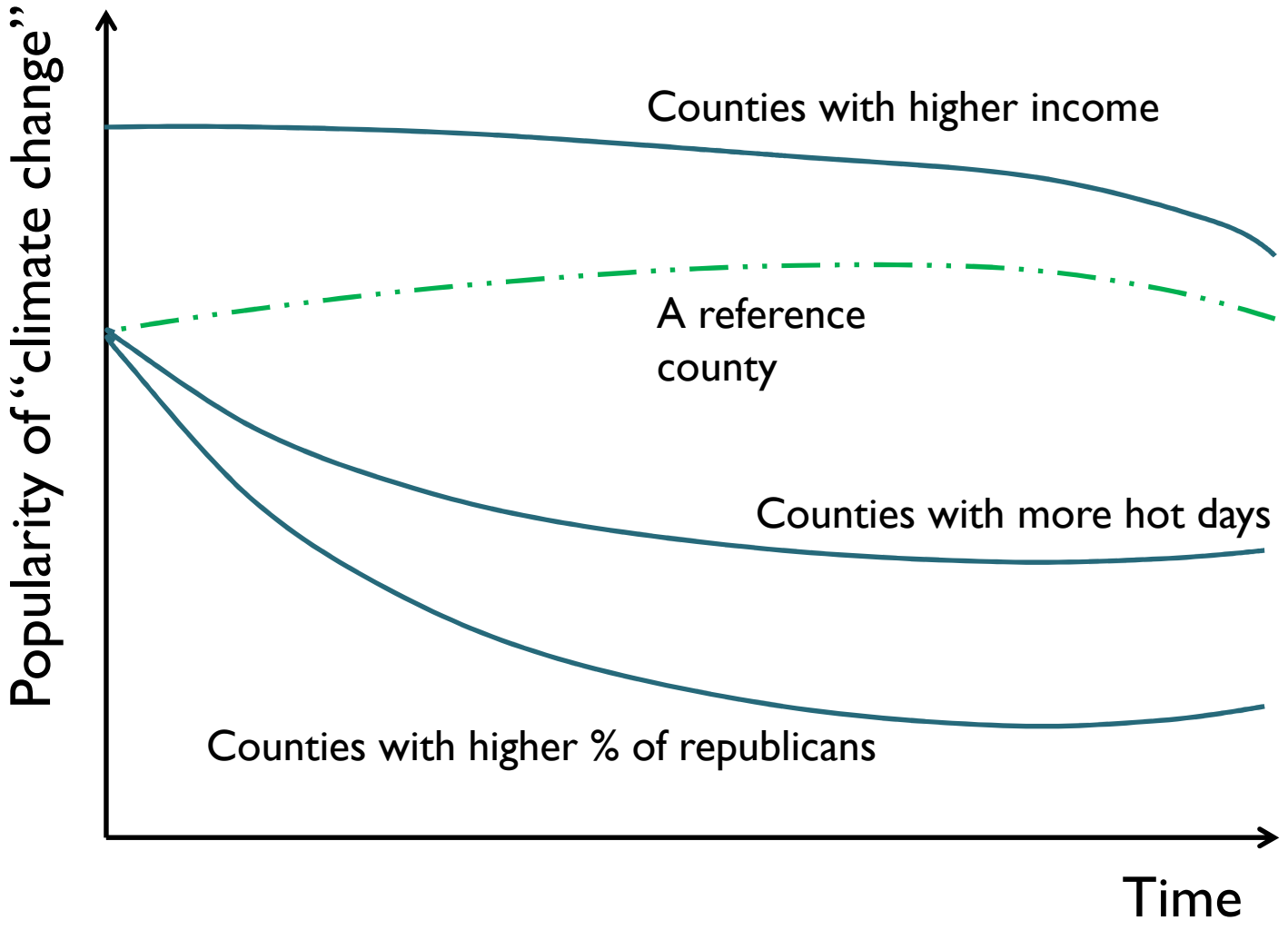
Latent trajectory modeling

(with spatial filtering)

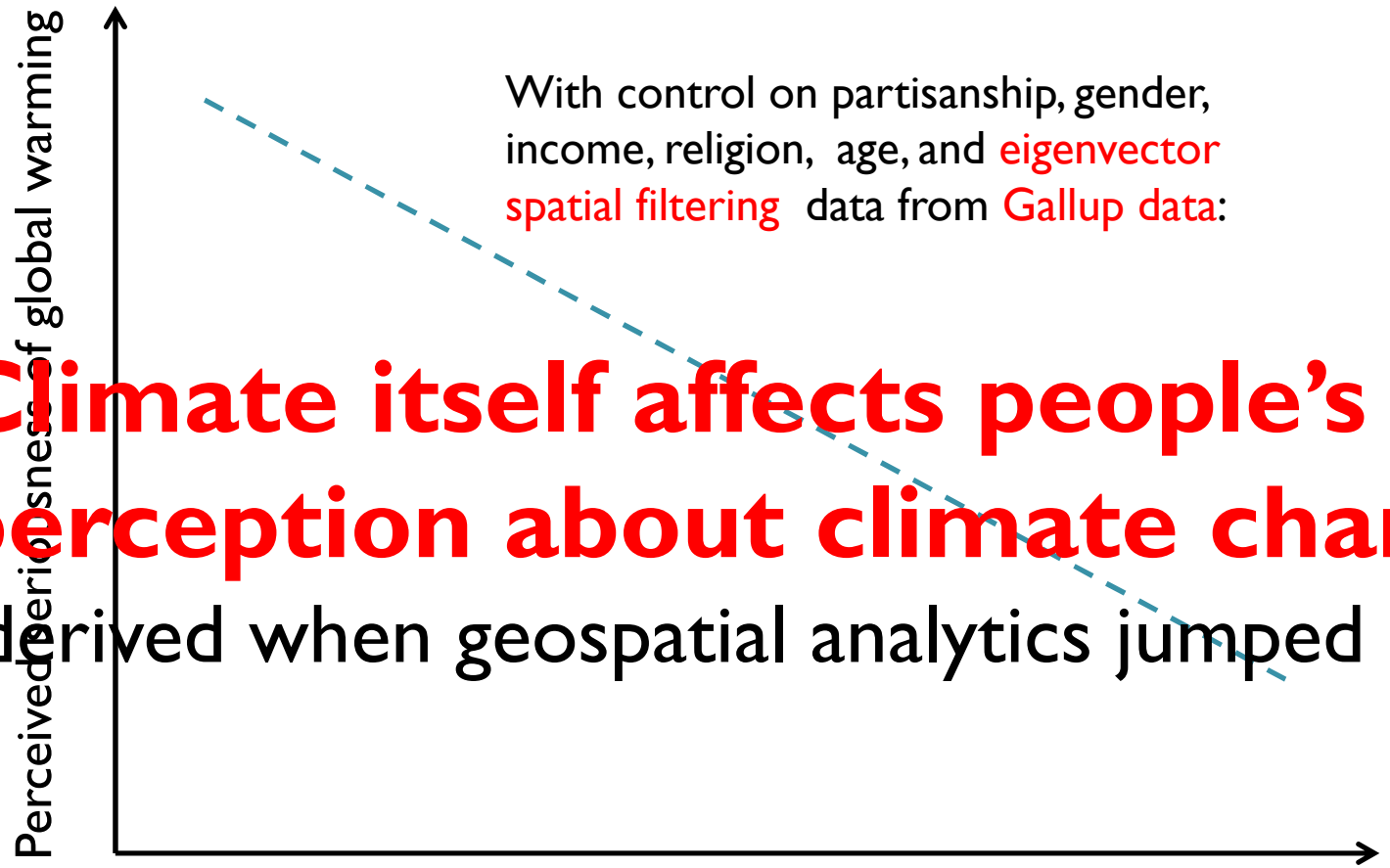
- Repeated measures
  - Underlying trajectory
  - Geospatially heterogeneous
- Trajectory parameters
  - Explained by chosen covariates
  - Spatial auto-correlated

An, L., M. Tsou, B. Spitzberg, J.M. Gawron, and D.K. Gupta (2016). Latent trajectory models for space-time analysis: An application in deciphering spatial panel data. *Geographical Analysis*.

Exemplar results



A geospatial divergent



Climate itself affects people's perception about climate change!

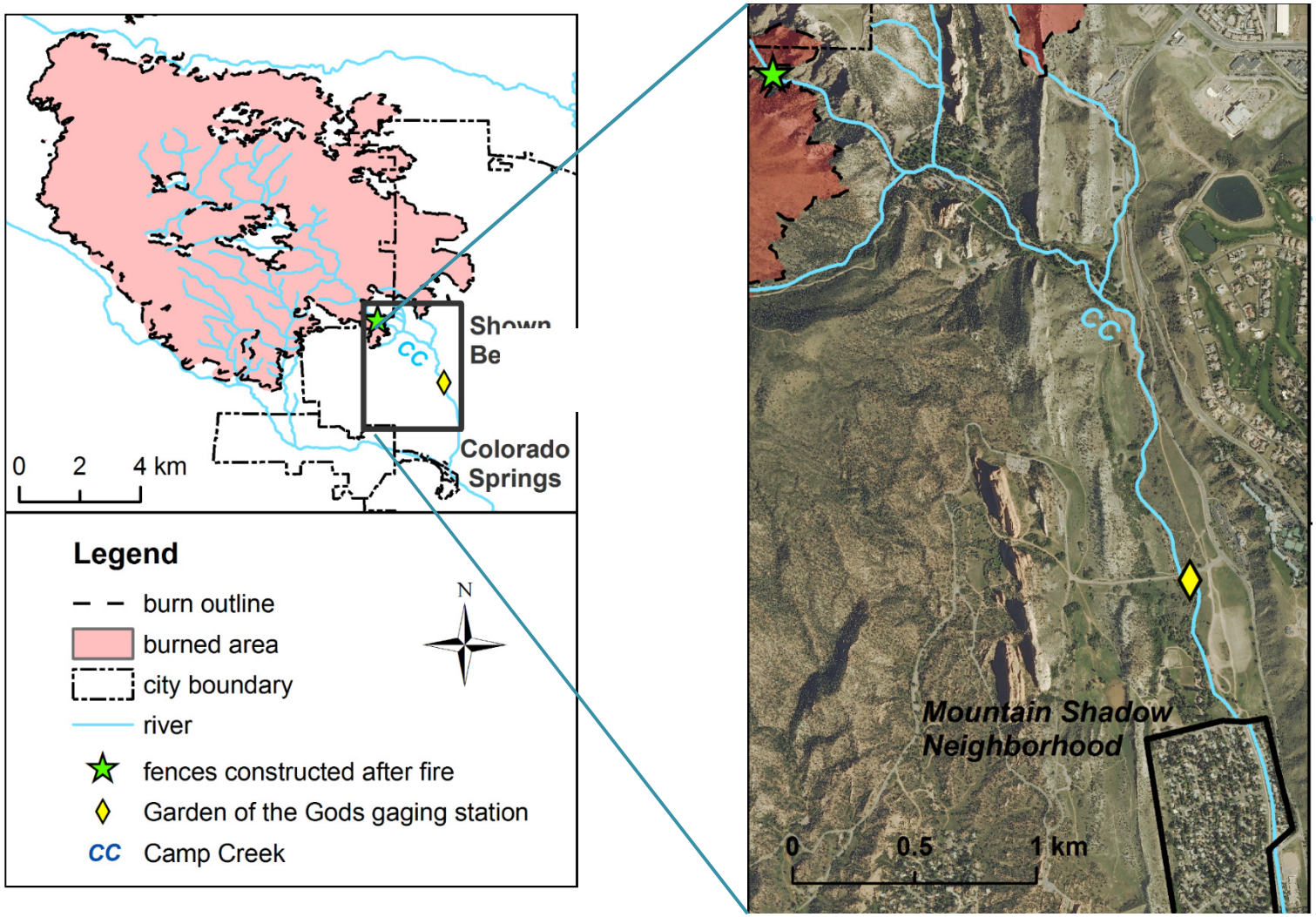
(derived when geospatial analytics jumped in)

Opportunities

- LTM methodology:
  - Body mass index (BMI) is well predicted by land use and land cover variables (Crook, An, Weeks et al. in revision).
  - Projects about obesity?
  - Projects about climate change induced climate change issues (impacts)?

Crook, S.E.S., L. An, D.A. Stow, and J.R. Weeks (in review). Latent trajectory modeling of spatiotemporal relationships between land cover and land use, socioeconomics, and obesity in Ghana. Spatial Demography.

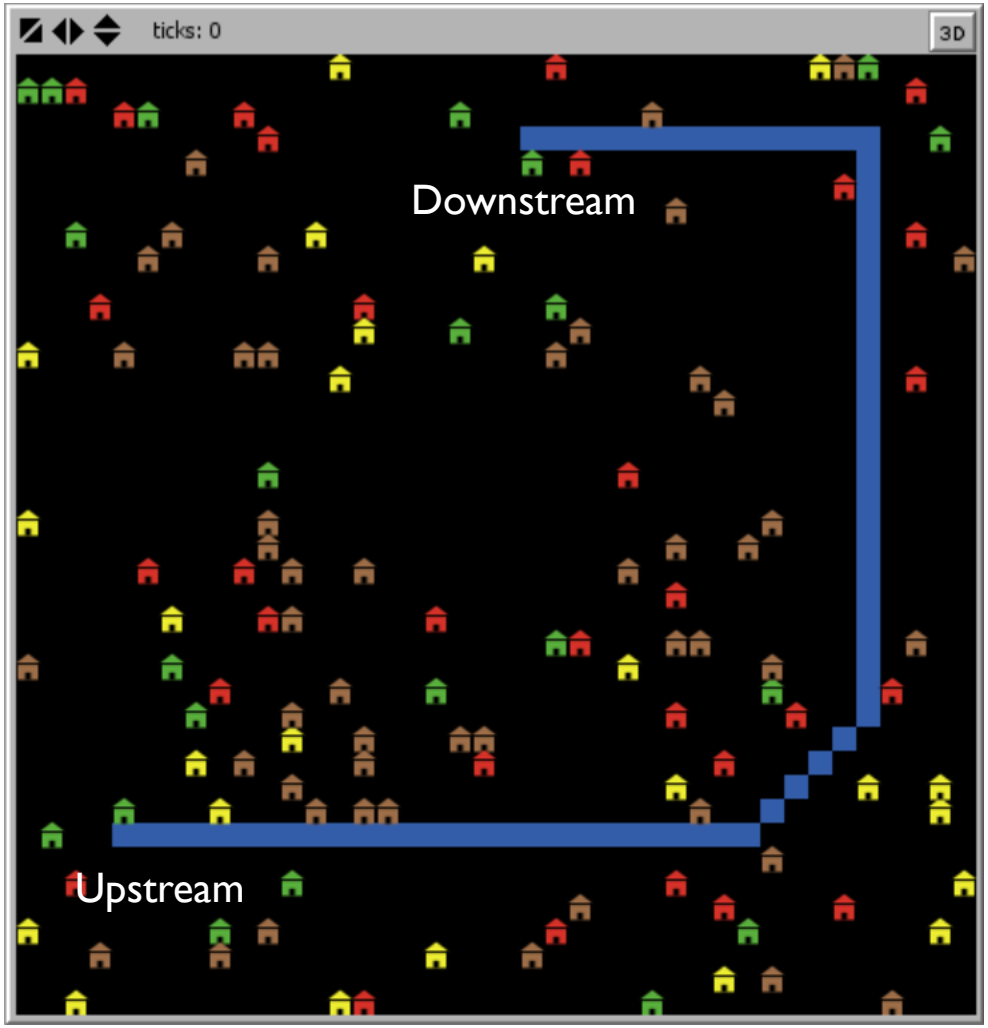
The Waldo Canyon Fire



Chin, A., **L. An**, J. Florsheim, L. Laurencio, R. Marston, A. Parker, G. Simon, and E. Wohl (2016). Feedbacks in human-landscape systems: lessons from the Waldo Canyon Fire of Colorado, USA. *Geomorphology* 252(2016): 40-50.

Put households into space!

- Households randomly located
  - Payment made to reduce sediment erosion
  - Social norm affects
  - Various levels of erosion tolerance
- Build an ABM
  - Partially empirical
  - Hypothesis testing about the above three factors



Payment: High (green) , Moderate (yellow), 1 (brown) , 0 (red)

Interestingly we found

Social norm, payment increment, and environmental tolerance **interact** with one another in a very **complex** way

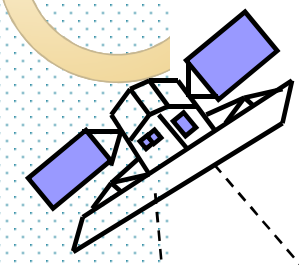
Opportunities

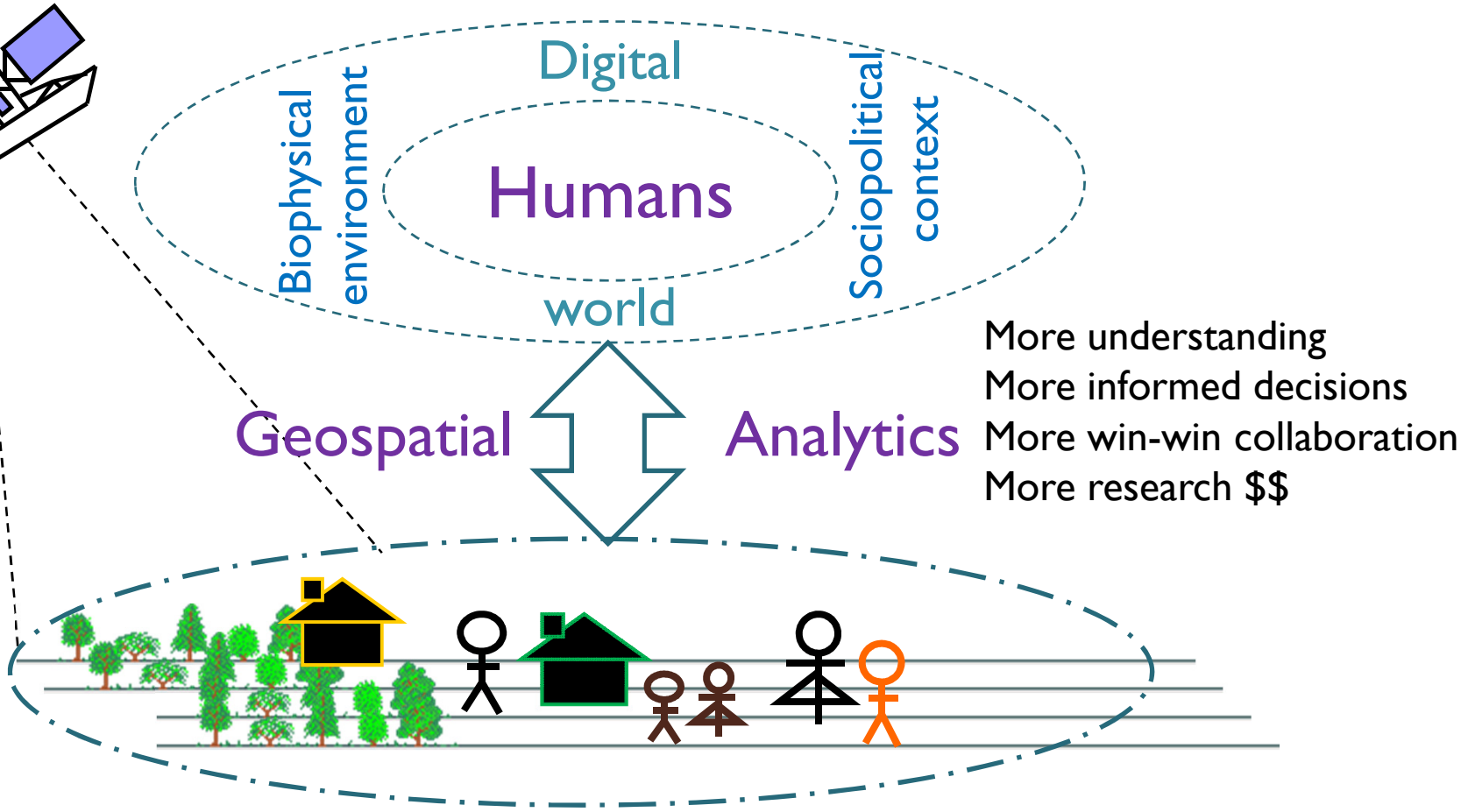
- Individual decisions and activities
  - Decision rules: some known some unknown—make assumptions!
  - Geovisualization, modeling, and simulation—mind experiments to inform policy
- Conservation of landscapes
  - Healthy and productive
  - Provide various ecosystem services

Human-environment research & geospatial analytics

- Human-environment systems
  - People's thoughts, attitudes, and perceptions
  - People's health and well-being
  - People's decision making
  - People actions, behavior, and change in the environment
- Geospatial analytics
  - Georepresentation and geovisualization
  - GIS (informed by remote sensed imagery)
  - Spatial analysis (space-time analysis and geospatialized statistical modeling)
  - Spatially explicit agent-based modeling

Geospatial Analytics for Human environment research





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  - **Cyber-enabled Discovery and Innovation (CDI) Program**
- **NASA Land Use and Land Cover Change Program**
- **NIH Population and Environment Program**
- **Fanjingshan National Nature Reserve, China**
- **Chinese Academy of Sciences**
- **San Diego State University**

THANK YOU

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