

# Using Fuzzy Cognitive Mapping as a Participatory Approach to Measure Change, Preferred States and Perceived Resilience of Social-Ecological Systems

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MentalModeler v0.2



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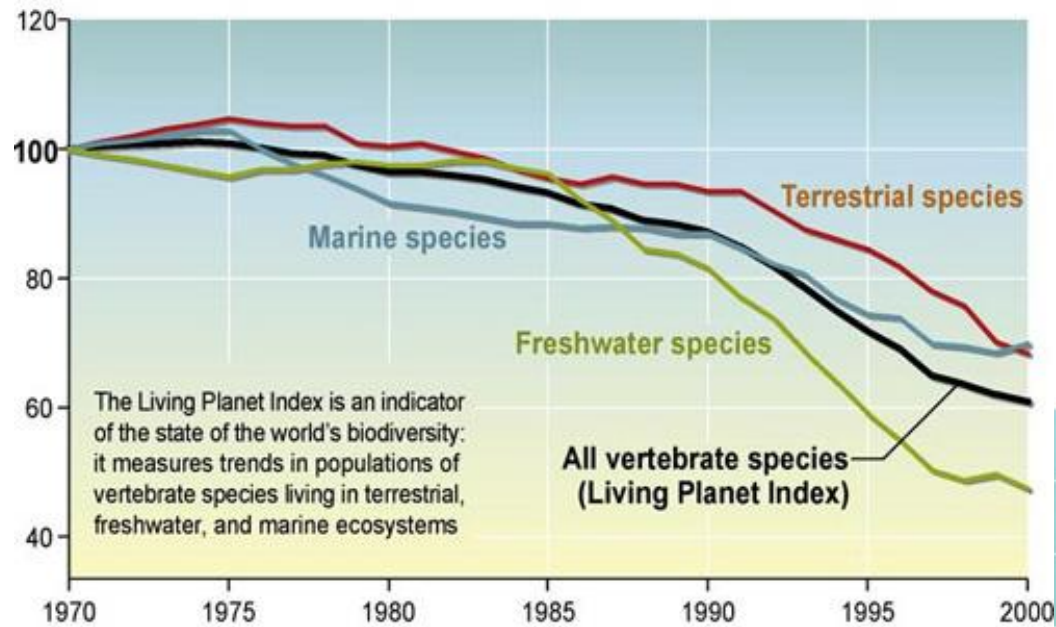
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# Vertebrate species decline since 1970

Population Index = 100 in 1970



The Living Planet Index is an indicator of the state of the world's biodiversity: it measures trends in populations of vertebrate species living in terrestrial, freshwater, and marine ecosystems

## Canadian cod collapse of the 1990s

Source: WWF, UNEP-WCMC



Source: Millennium Ecosystem Assessment

# Goals for Natural Resource Mgt.

“Command and control” approaches are not sustainable (Holling and Keith, 1996).

Need to make decisions which are adaptive  
(Walker et al., 2002).

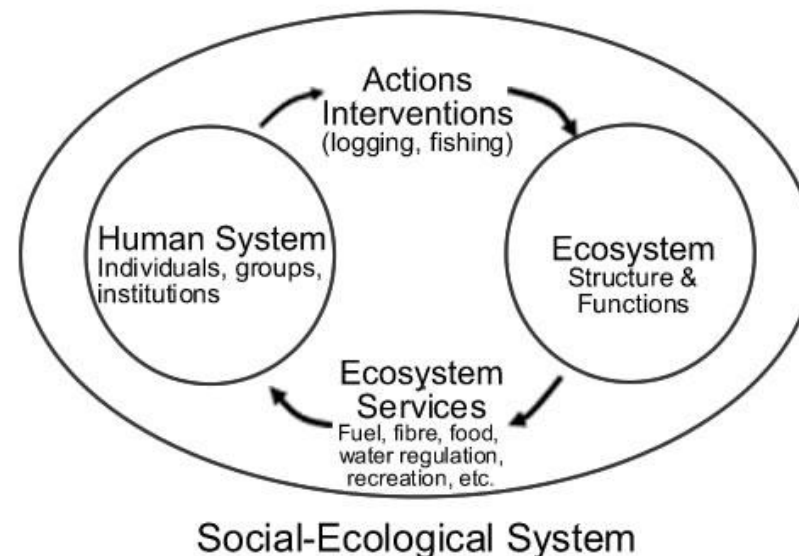
Need to incorporate complexity and human dimensions in  
to management decision-making (Agrawal and Gibson,  
1999).

Need to develop participatory approaches to  
understanding the complexity and dynamics of natural  
resources (Walker et al., 2002)

Engineer natural resource systems for resilience (Holling 1987)

# Social-Ecological Systems

consists of a bio-geo-physical unit and its associated social actors and institutions. SES are complex and adaptive and delimited by spatial or functional boundaries (Glaser et al., 2008).



# Outline

## **Understanding Resilience**

- Background
- Defining useful terms and Concepts



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- Community-based FCM construction
- Defining Preferred Change and Preference State of an SES

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# Resilience

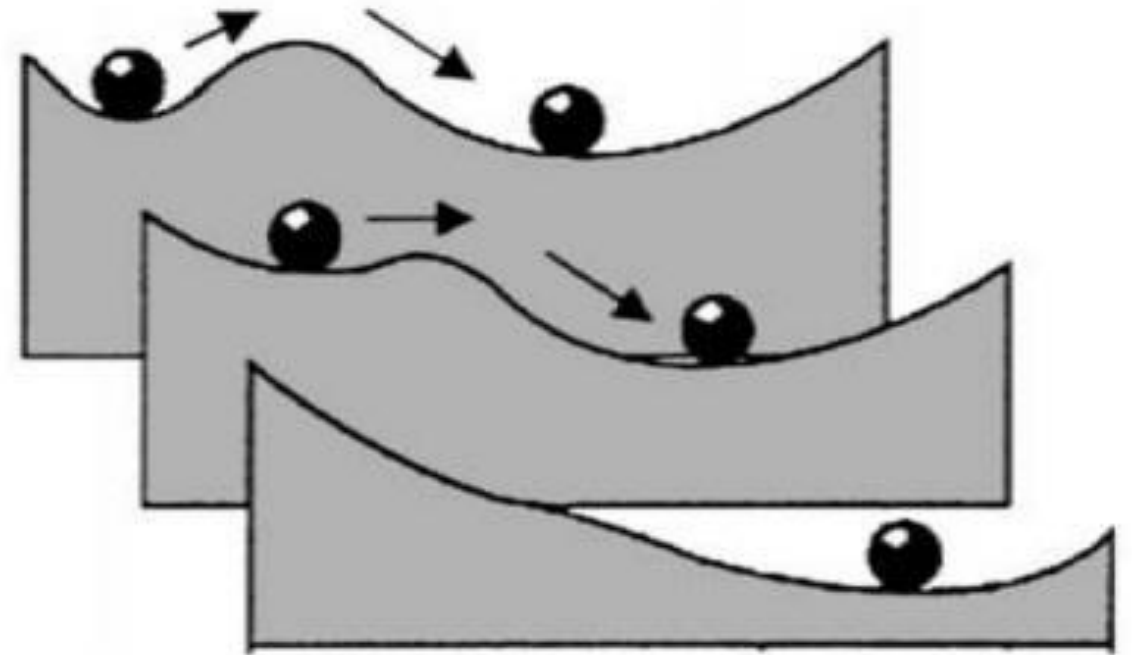
- Over the last several years, considerable research effort has been dedicated to understanding the drivers of change within social-ecological systems (SESs) that can alter the system's function to the point where human well-being, conservation, or other environmental management goals are compromised. These research efforts have focused primarily **on analyzing and understanding the attributes governing these systems' dynamics, specifically those significant enough to shift the system into an alternative regime** (Walker et al. 2004).

# Resilience

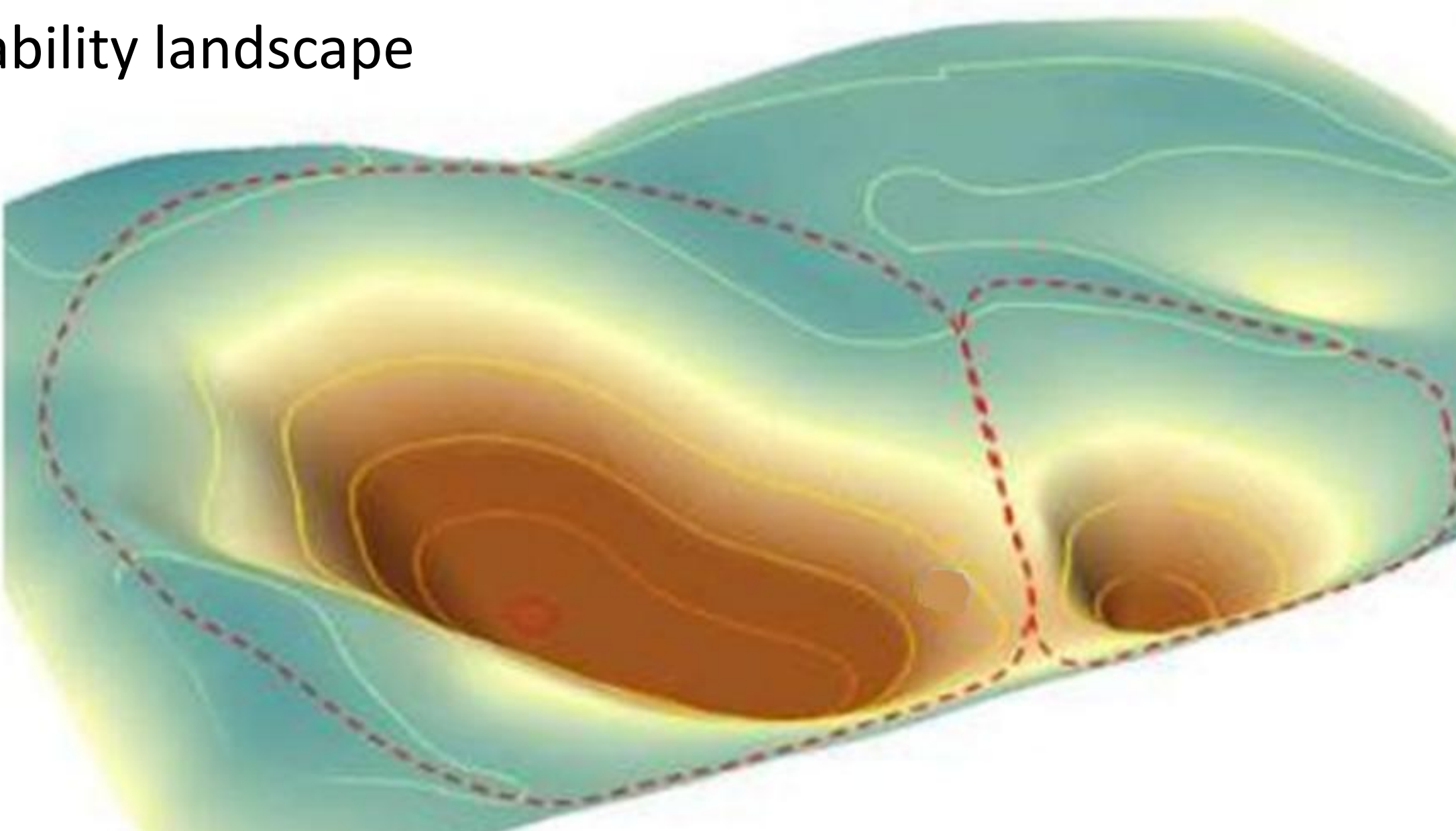
Although there are some variations in the literature with regard to the definition of resilience (Brand and Jax 2007) depending on the application in either an ecological (Holling 1973, Gunderson and Holling 2002) or social (Adger 2000) system context, it is generally considered to be **the capacity of a system to experience shocks while retaining a certain qualitative condition, including the same identity, structure, functions, and feedbacks** (Walker et al. 2004).

# Resilience

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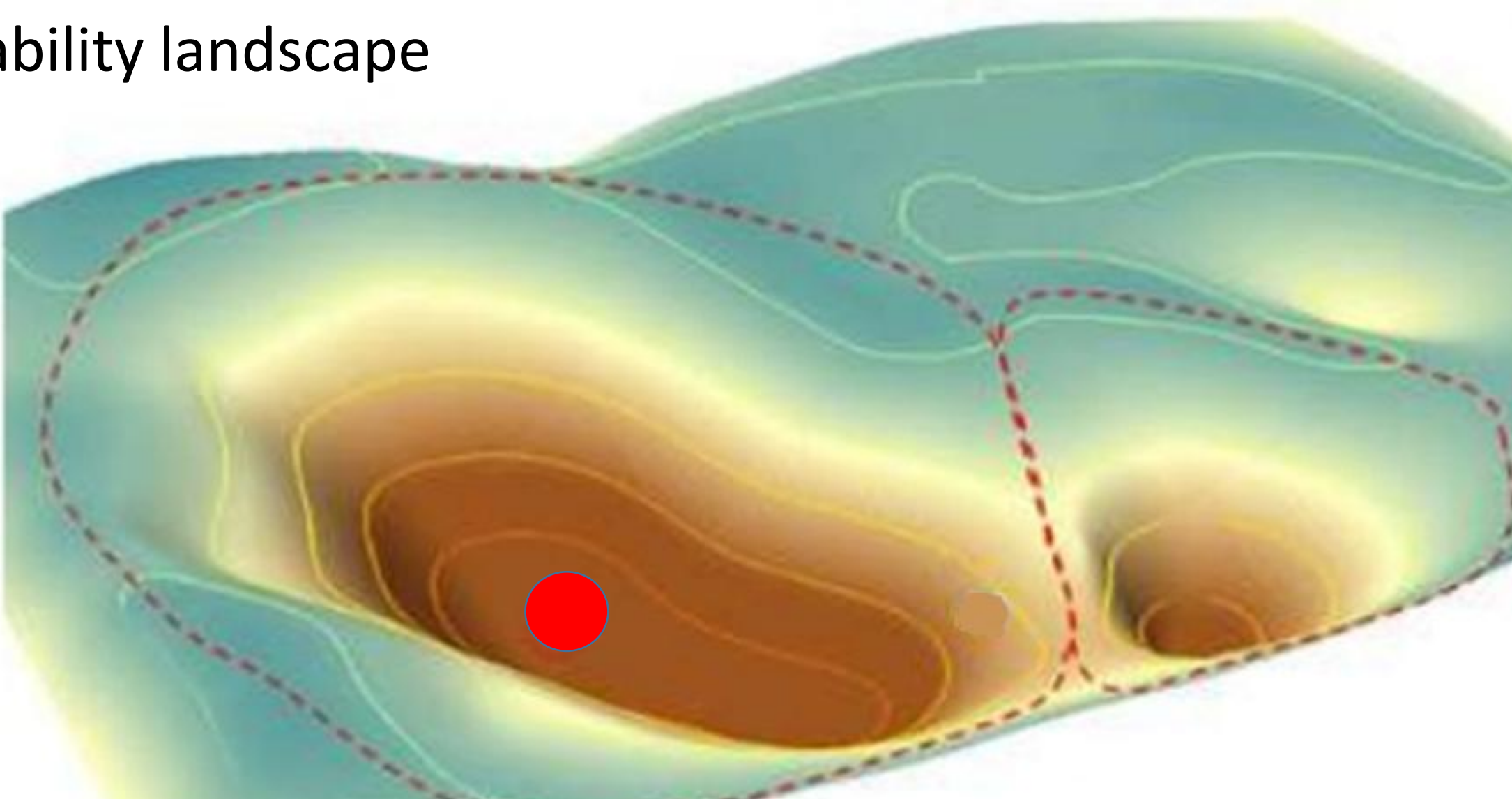
# Stability landscape



Walker et al. (2004)



# Stability landscape

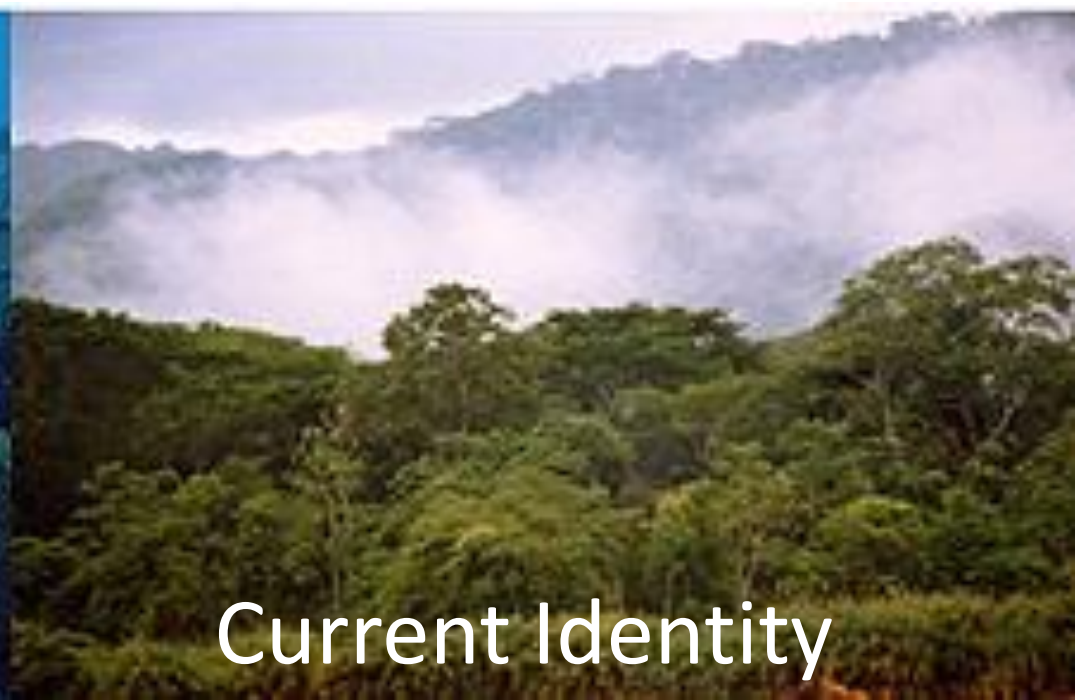


Walker et al. (2004)

**Basin of attraction:** region in state space in which the system tends to remain



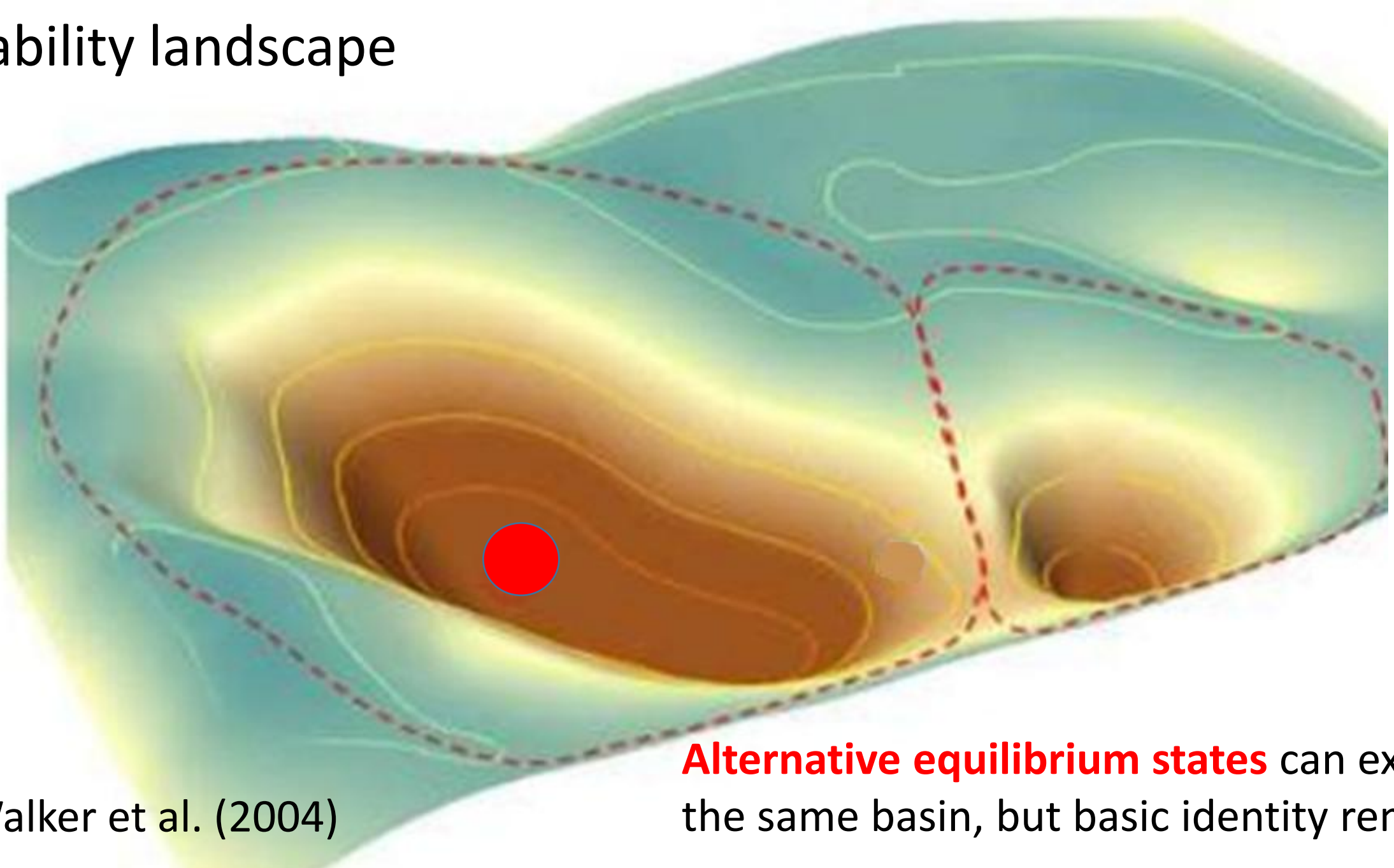
Current Identity



Current Identity

Folke et al. (2004)

# Stability landscape

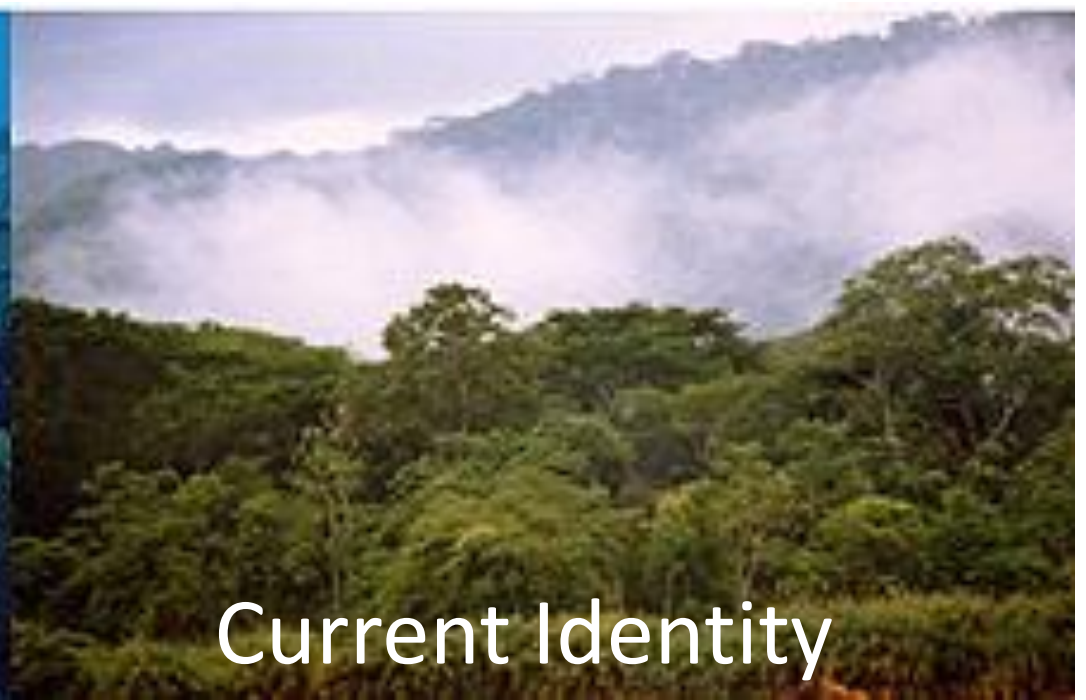


Walker et al. (2004)

**Alternative equilibrium states** can exist in the same basin, but basic identity remains



Current Identity



Current Identity

Folke et al. (2004)



**Change in ocean temperature**  
Increased ocean temperature caused by climate change is the leading cause of coral bleaching.



**Runoff and pollution**  
Storm generated precipitation can rapidly dilute ocean water and runoff can carry pollutants — these can bleach near-shore corals.



**Overexposure to sunlight**  
When temperatures are high, high solar irradiance contributes to bleaching in shallow-water corals.



**Extreme low tides**  
Exposure to the air during extreme low tides can cause bleaching in shallow corals.



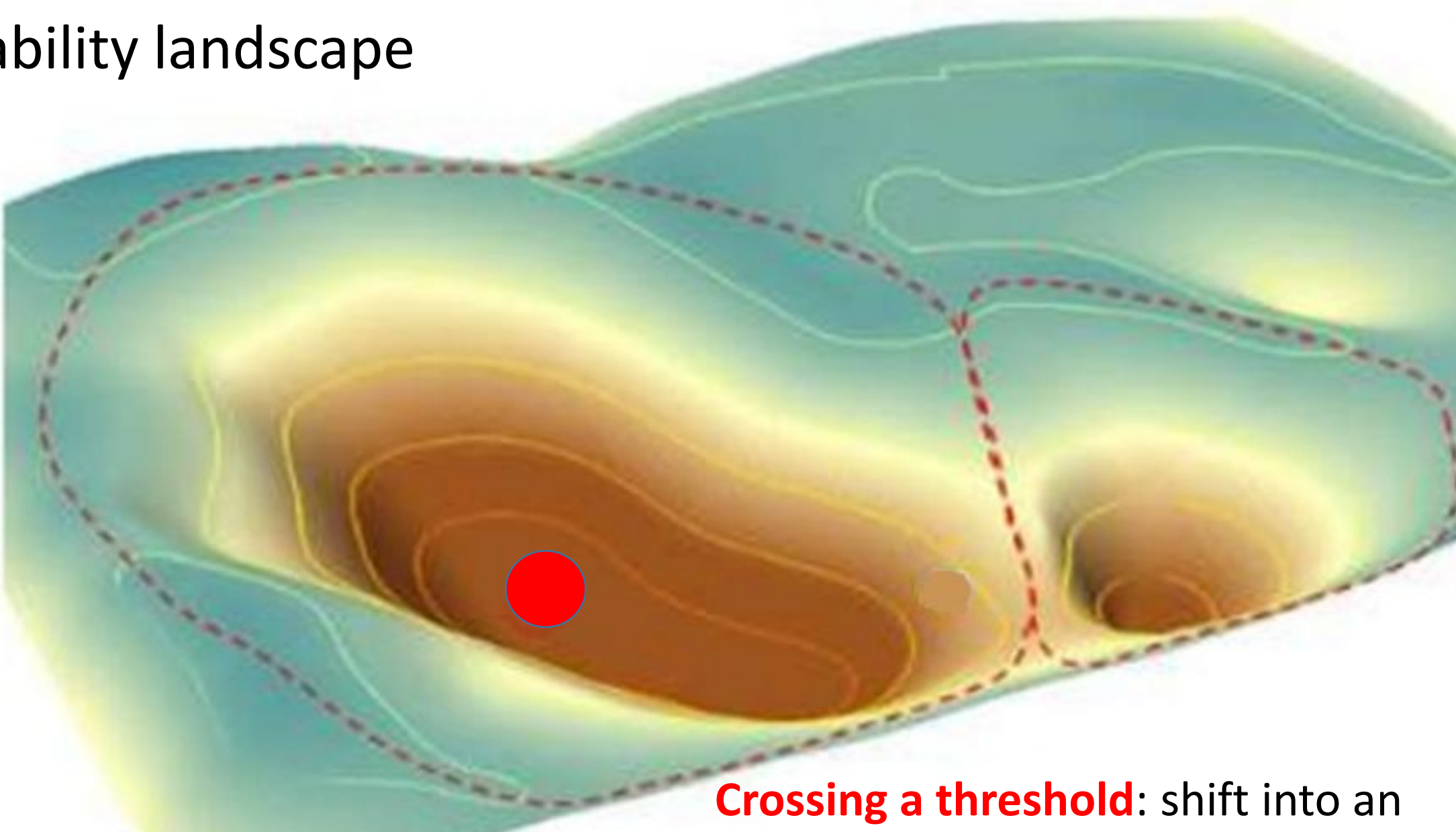
Current Identity



Current Identity

Folke et al. (2004)

# Stability landscape



Walker et al. (2004)

**Crossing a threshold:** shift into an alternative stable state with a new identity



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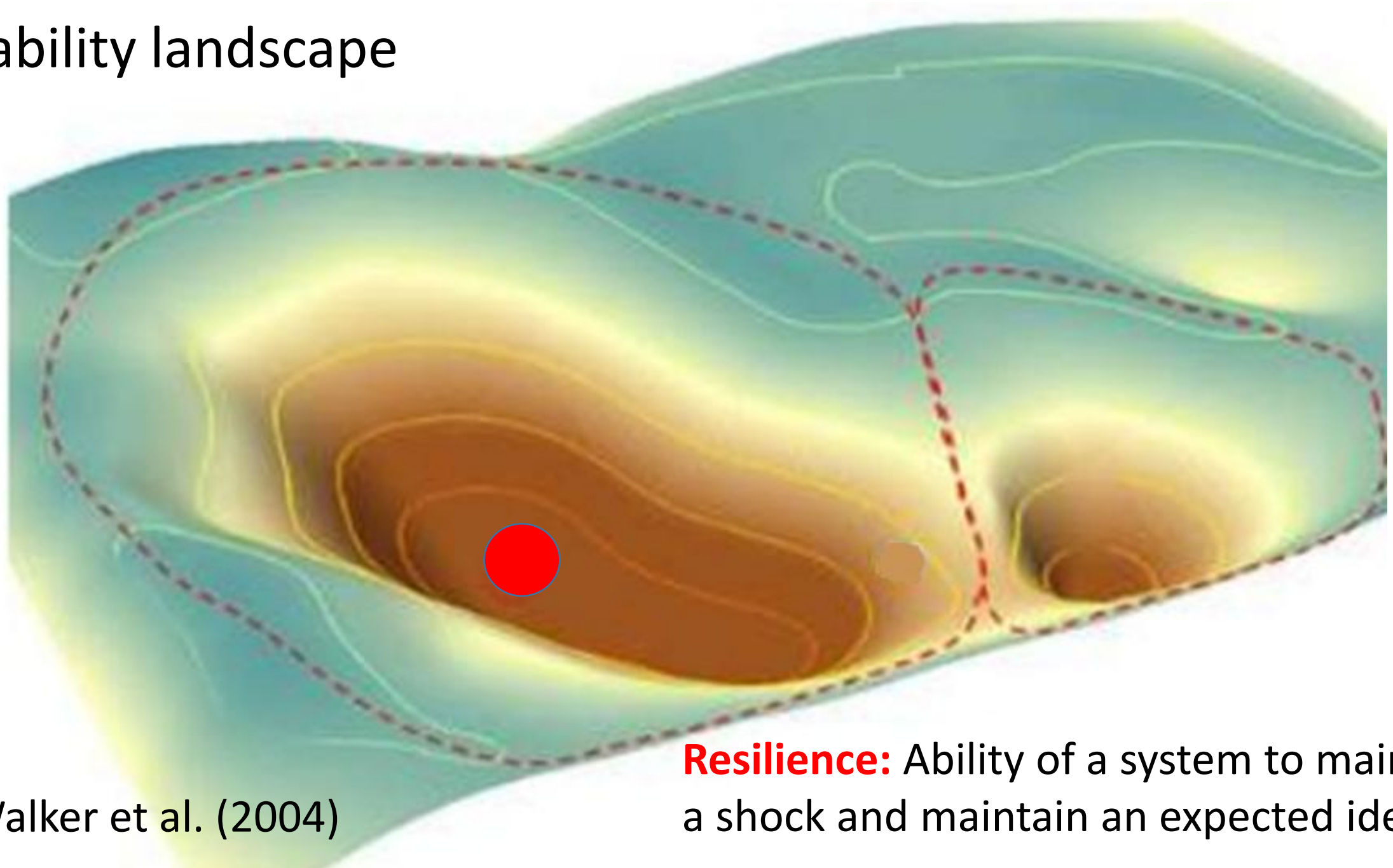
Threshold Crossed



New Identity

Folke et al. (2004)

# Stability landscape

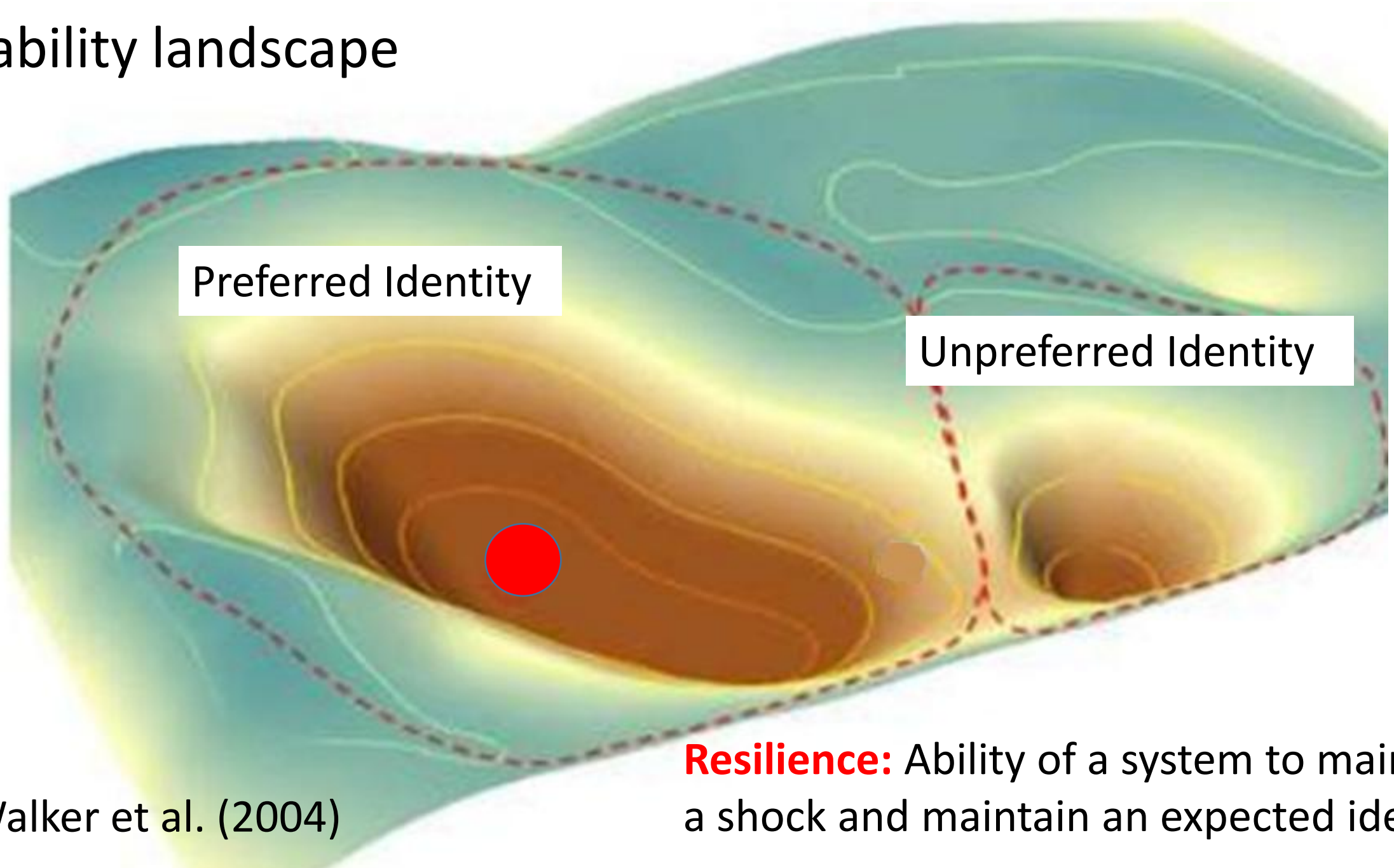


Walker et al. (2004)

**Resilience:** Ability of a system to maintain a shock and maintain an expected identity



# Stability landscape



Walker et al. (2004)

**Resilience:** Ability of a system to maintain a shock and maintain an expected identity



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# Fuzzy-logic Cognitive Mapping

A **Fuzzy cognitive map** is a cognitive map within which the relations between the elements (e.g. concepts, events, project resources) of a "mental landscape" can be used to compute the "strength of impact" of these elements.

Spreadsheets or tables are used to map FCMs into matrices for further computation. Reliant on fuzzy logic AND cognitive mapping



Bart Kosko  
Professor, USC

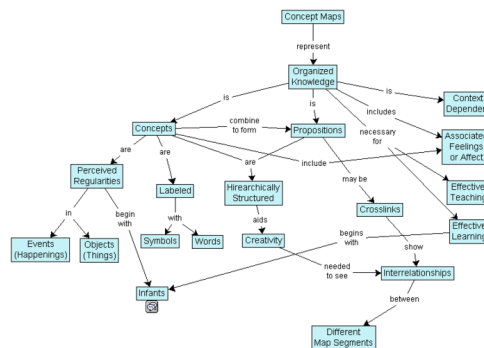
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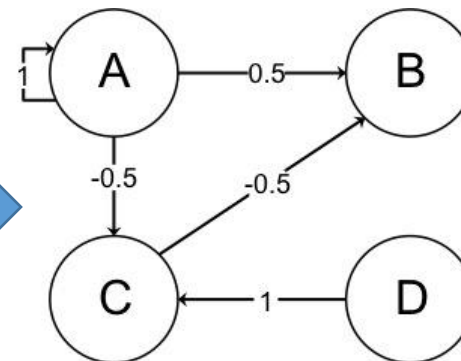
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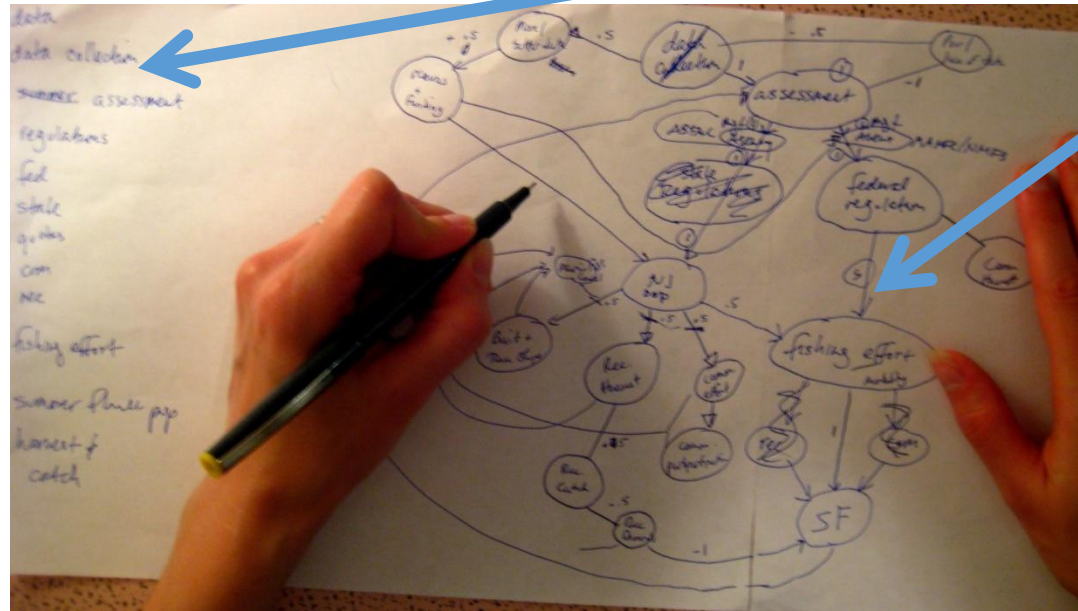


Static Associations



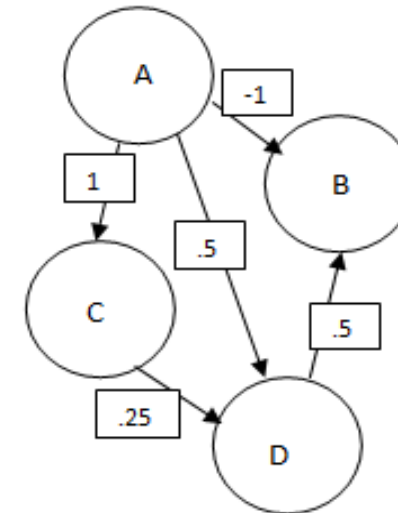
Dynamic Associations

# Understanding the System



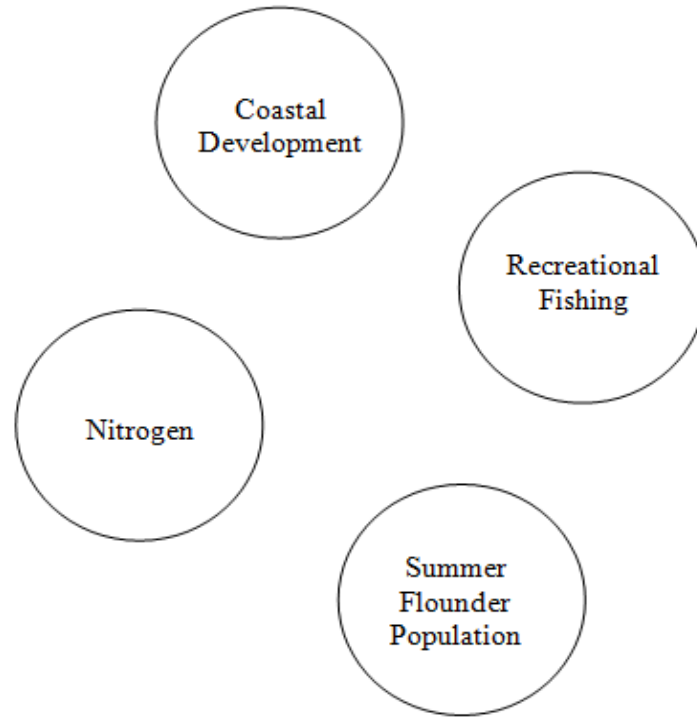
Components within the System(s)

Amount of positive or negative influence between components

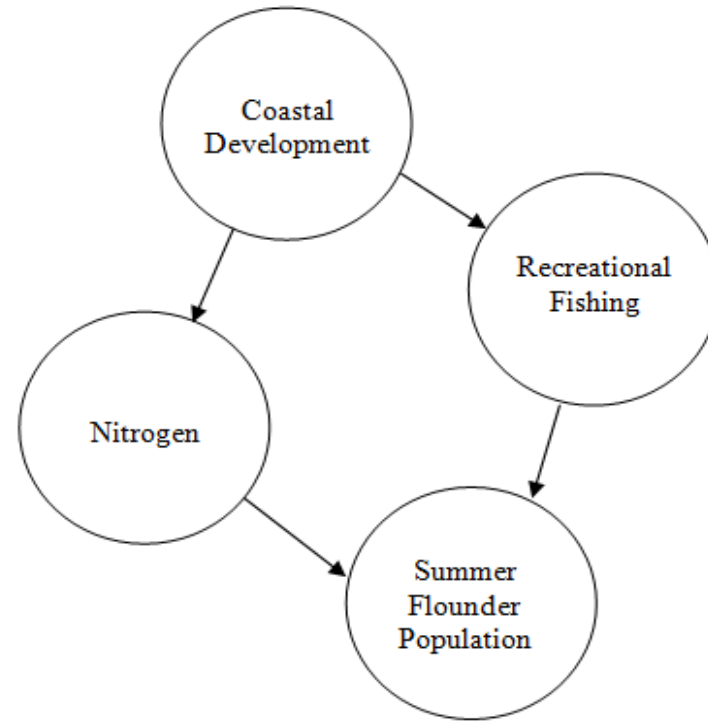


Stakeholder1 Map

# Define the components in the system



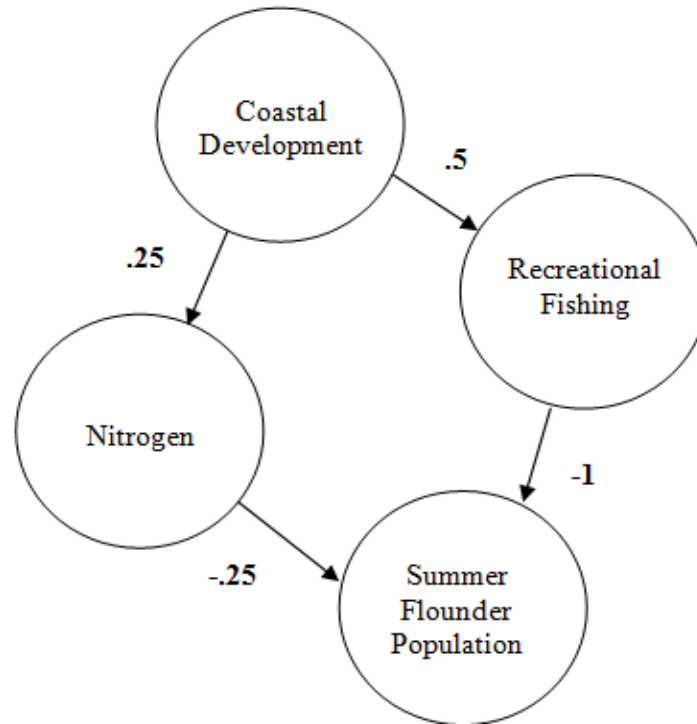
# Define the relationships



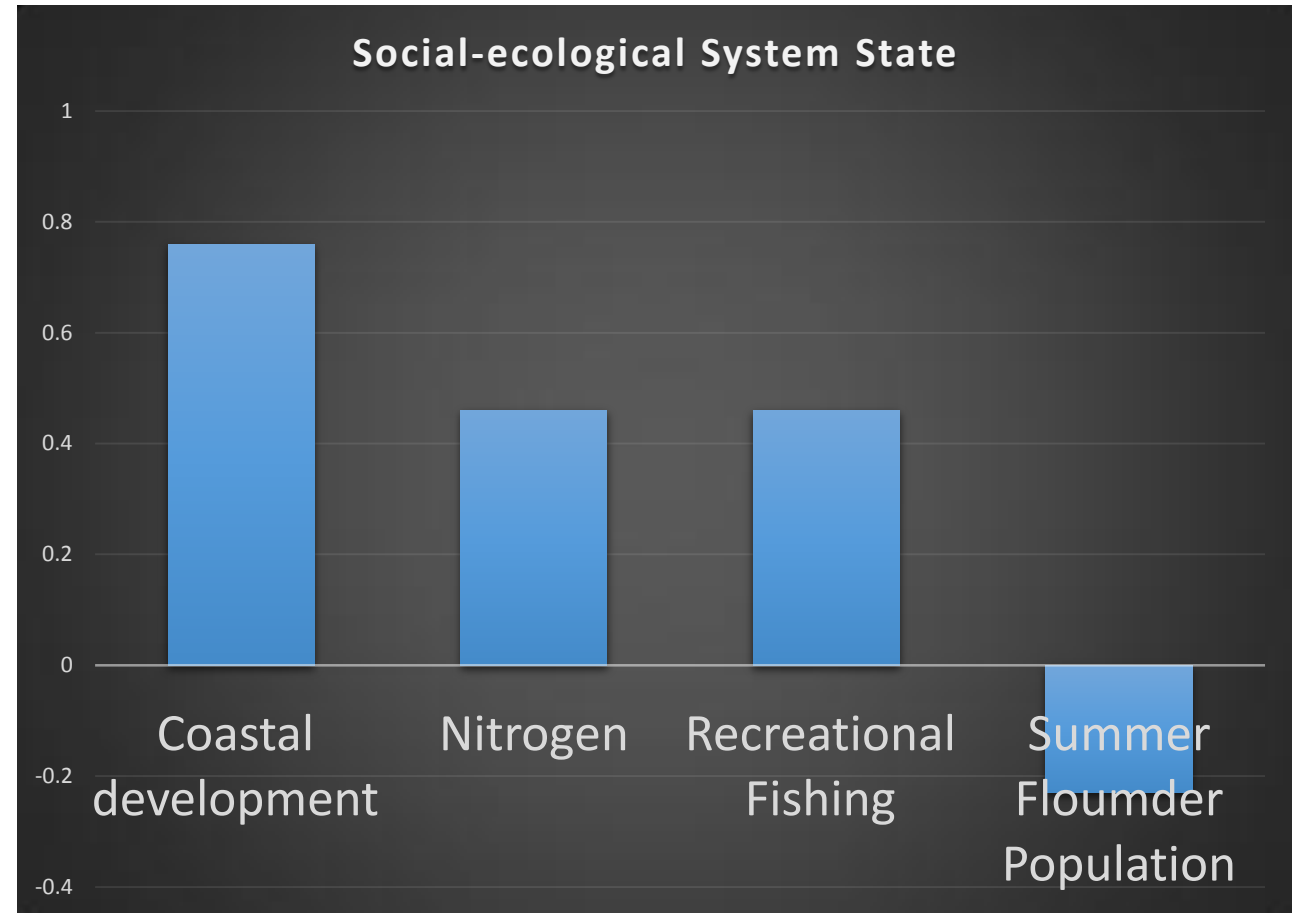
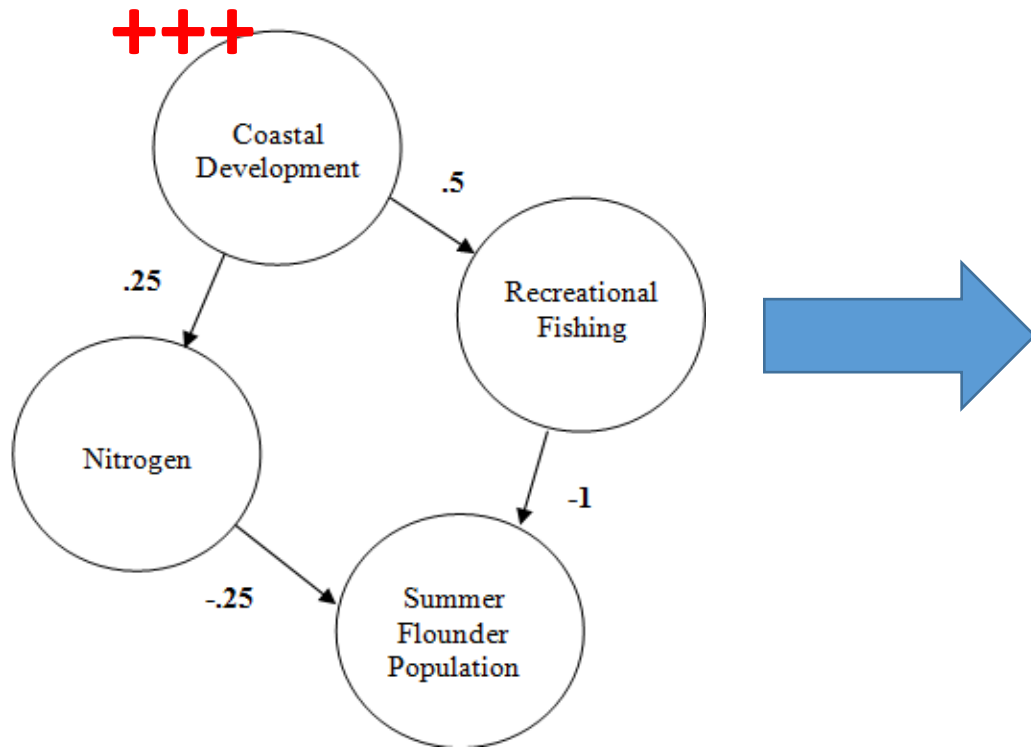


# Define the amount of influence

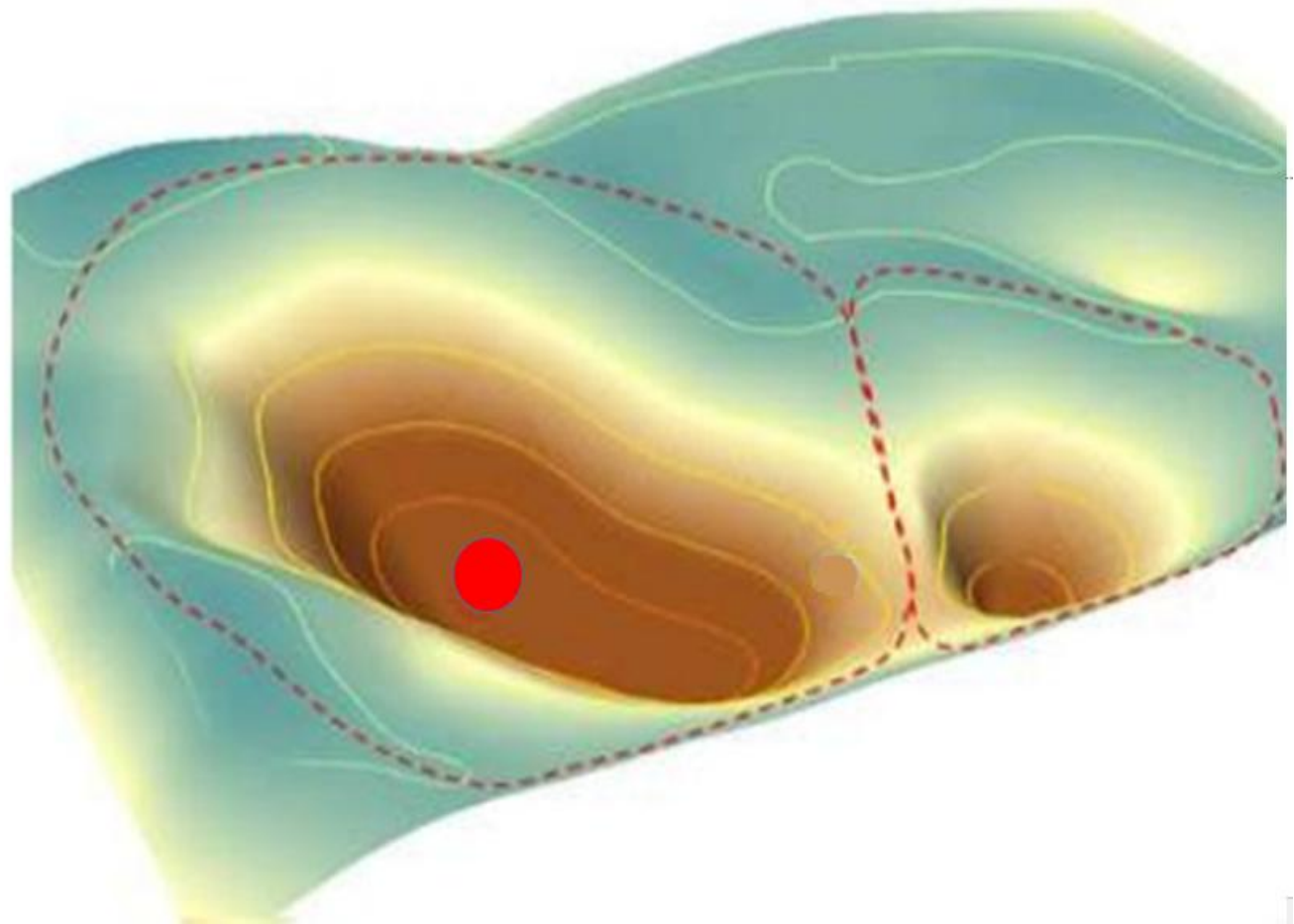
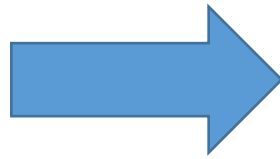
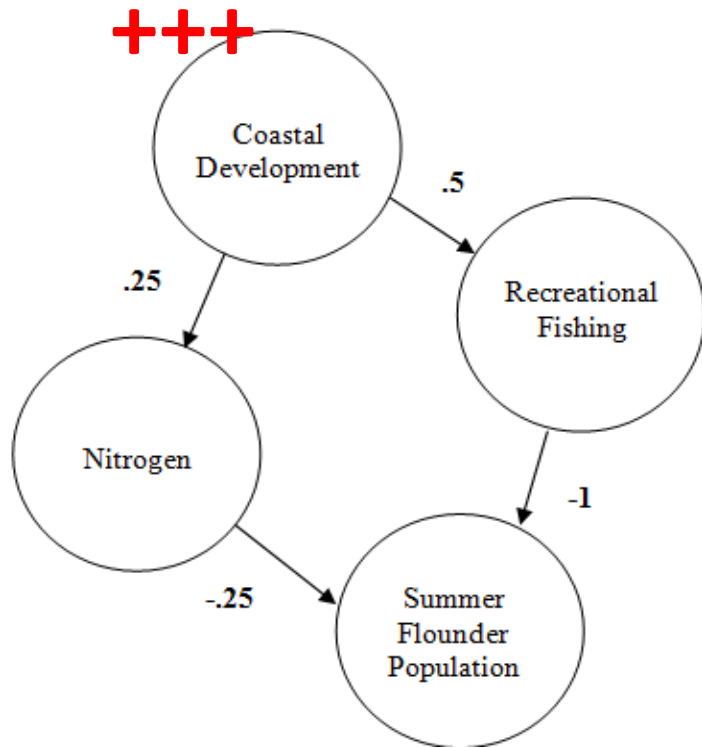
+1 Strong Positive  
+.5 Medium Positive  
+.25 Low Positive  
-----  
-1 Strong Negative  
-.5 Medium Negative  
-.25 Low Negative

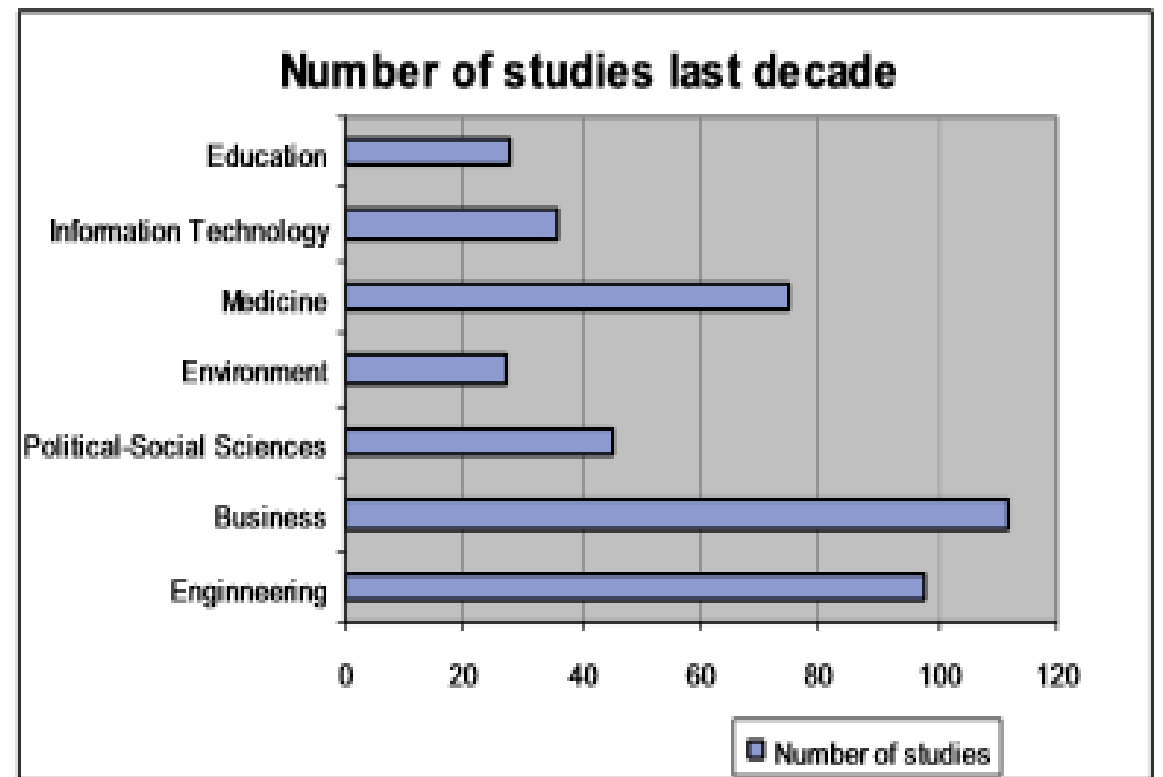
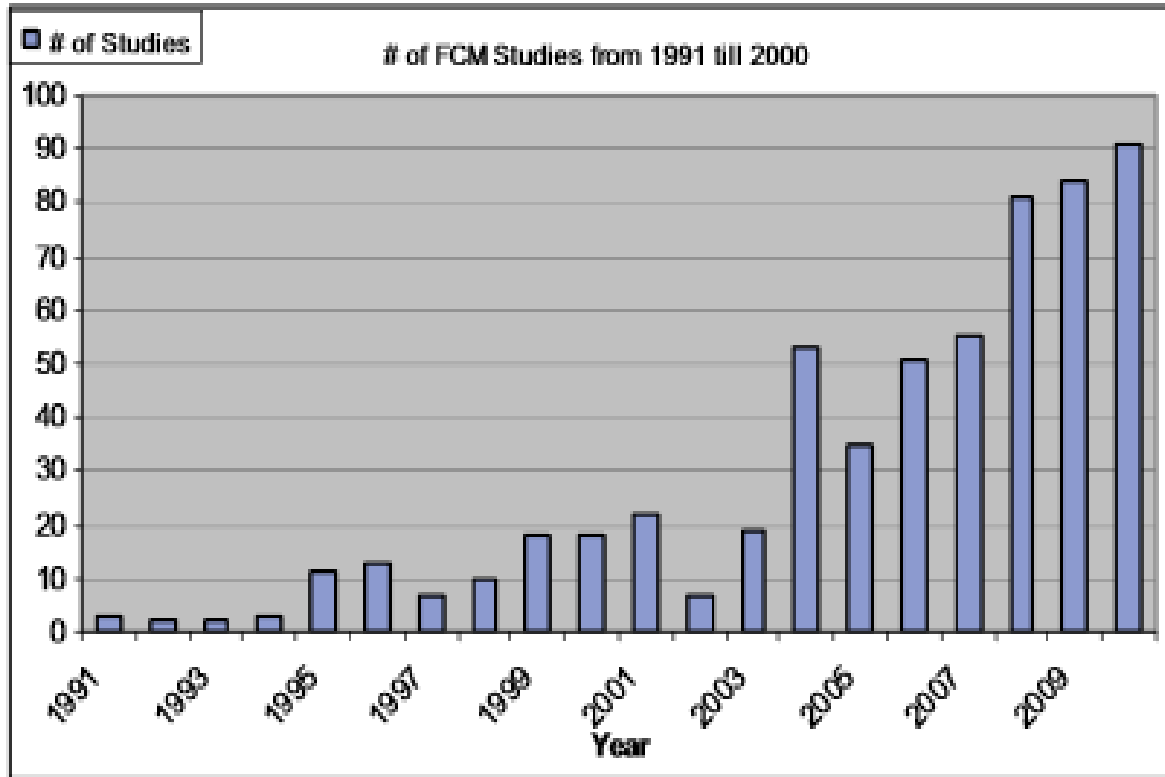


# Scenario Analysis

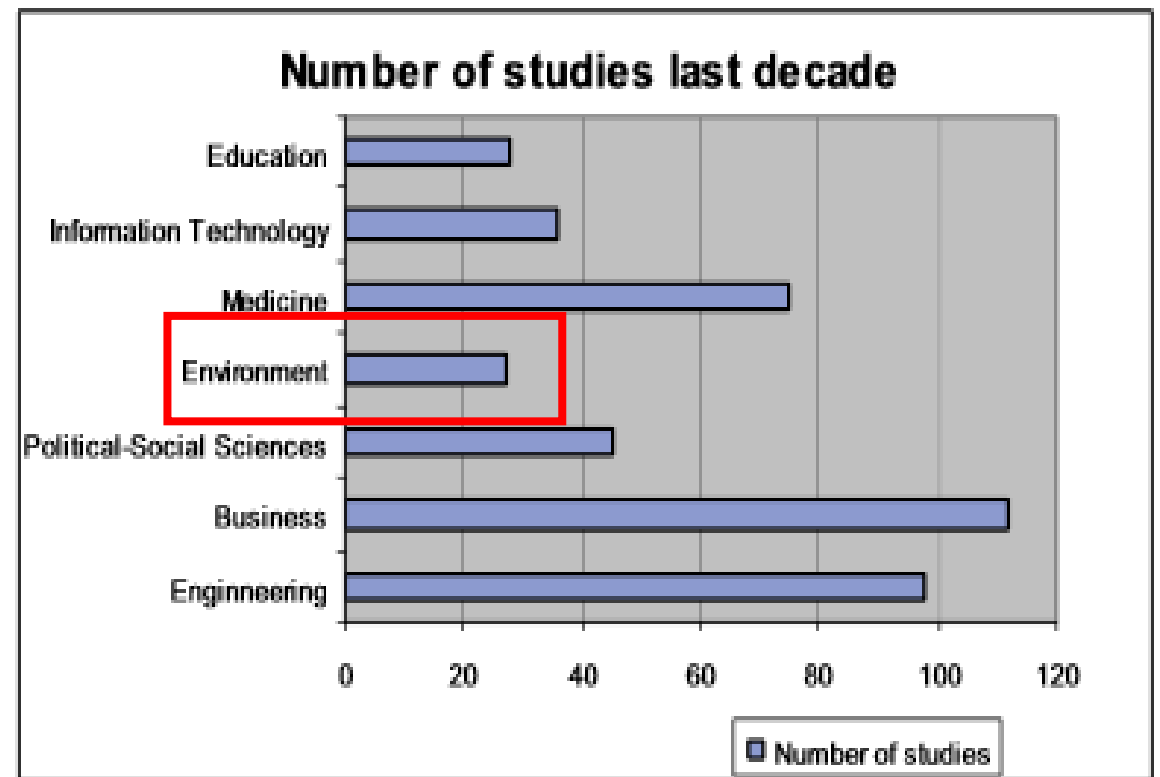
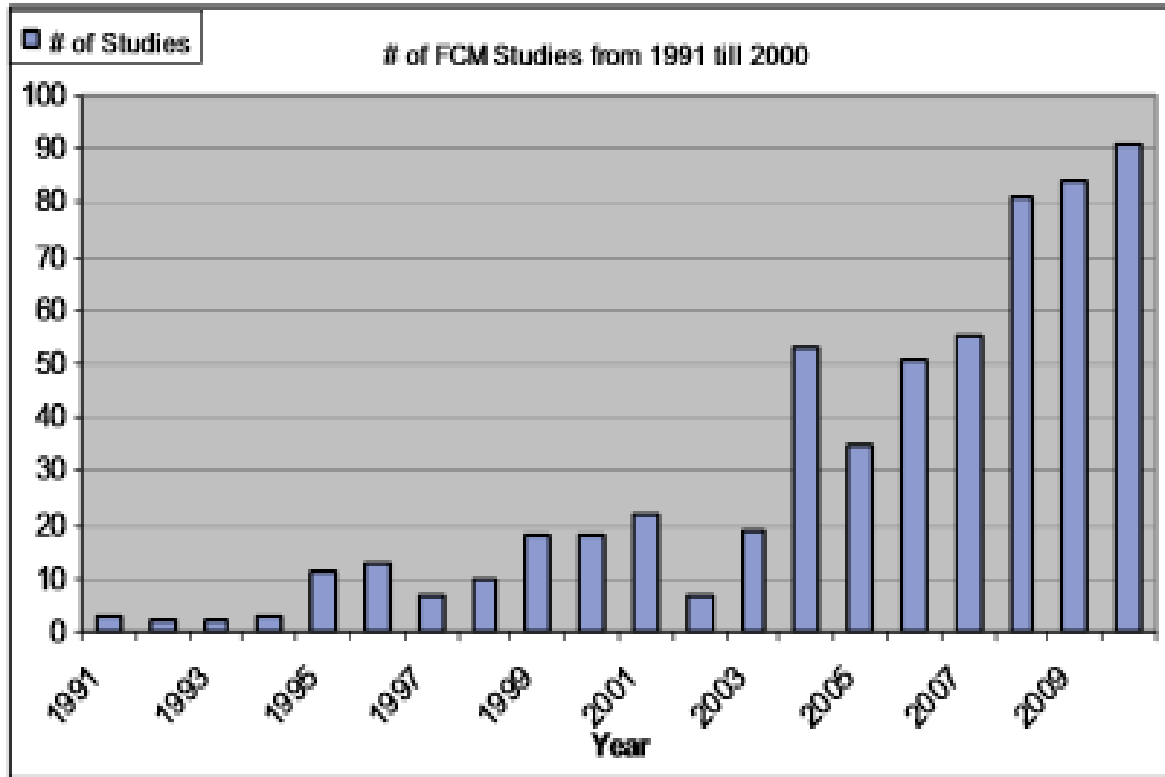


# Scenario Analysis





Papageorgiou (2011)

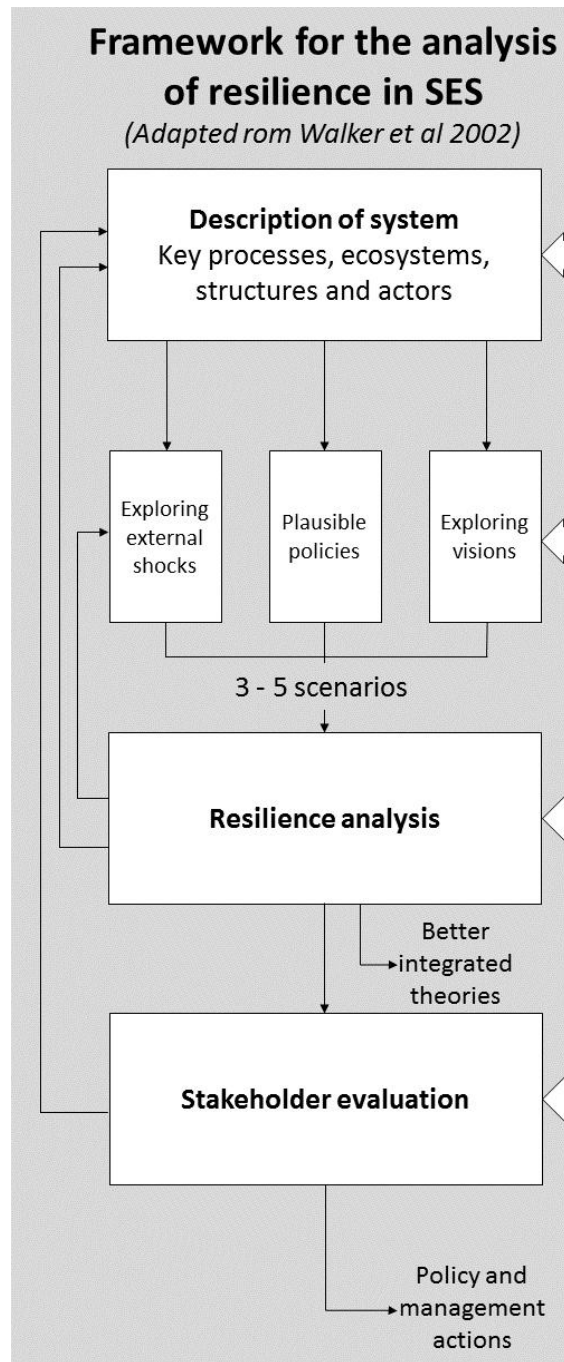


Papageorgiou (2011)

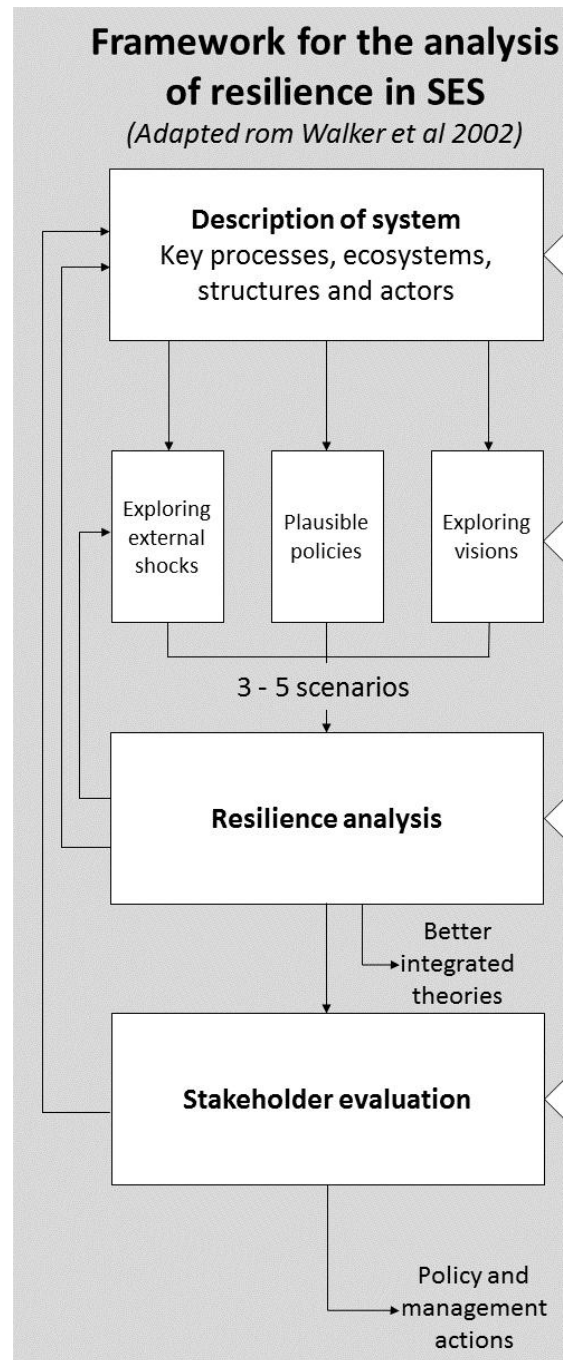
I am not the first...

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. S. Cumming, M. Janssen, L. Lebel, J. Norberg, G. D. Peterson, and R. Pritchard. 2002. ***Resilience management in social-ecological systems: a working hypothesis for a participatory approach.*** Conservation Ecology 6(1): 14. [online] URL: <http://www.consecol.org/vol6/iss1/art14/>

- 1. Define system structure and dynamics relationships

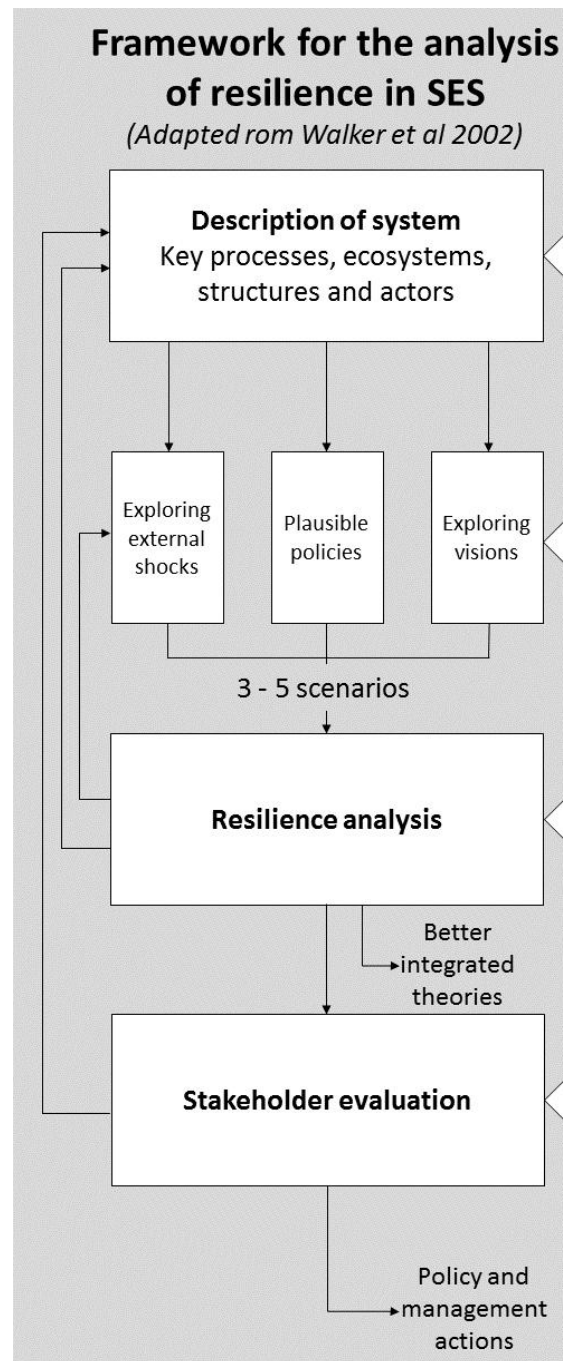


- 1. Define system structure and dynamics relationships
- 2. Explore shocks and policy influence

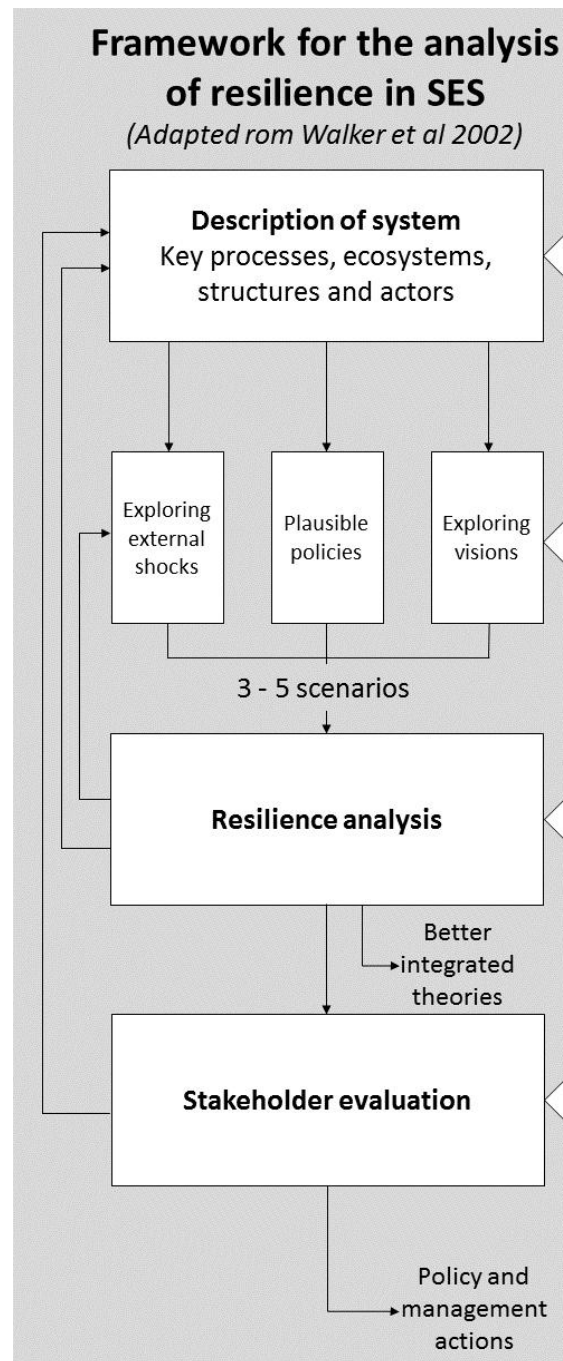




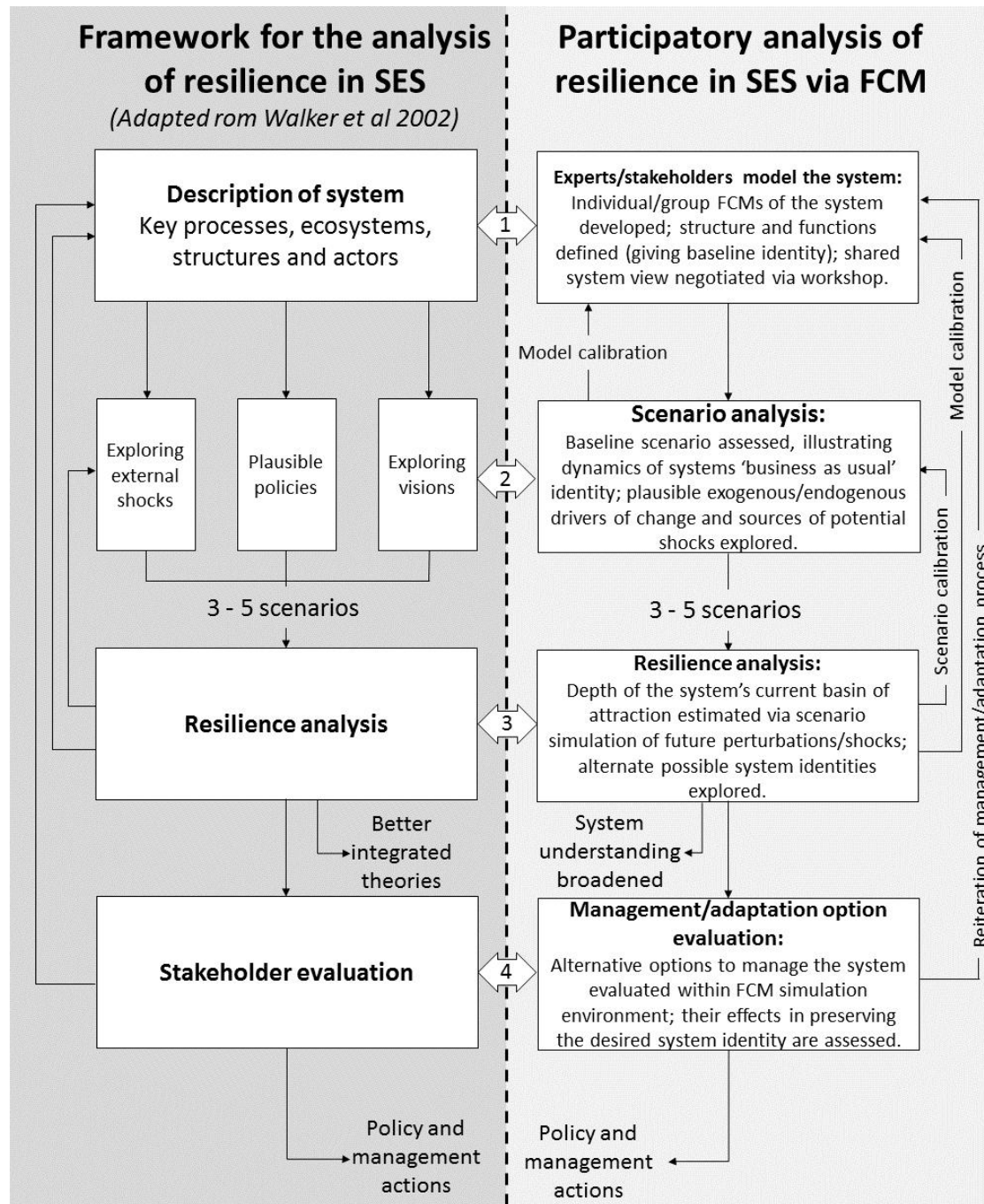
- 1. Define system structure and dynamics relationships
- 2. Explore shocks and policy influence
- 3. Analyze the systems ability to maintain a function



- 1. Define system structure and dynamics relationships
- 2. Explore shocks and policy influence
- 3. Analyze the systems ability to maintain a function
- 4. Reevaluate and incorporate new understanding revised model or adopt policy adoption

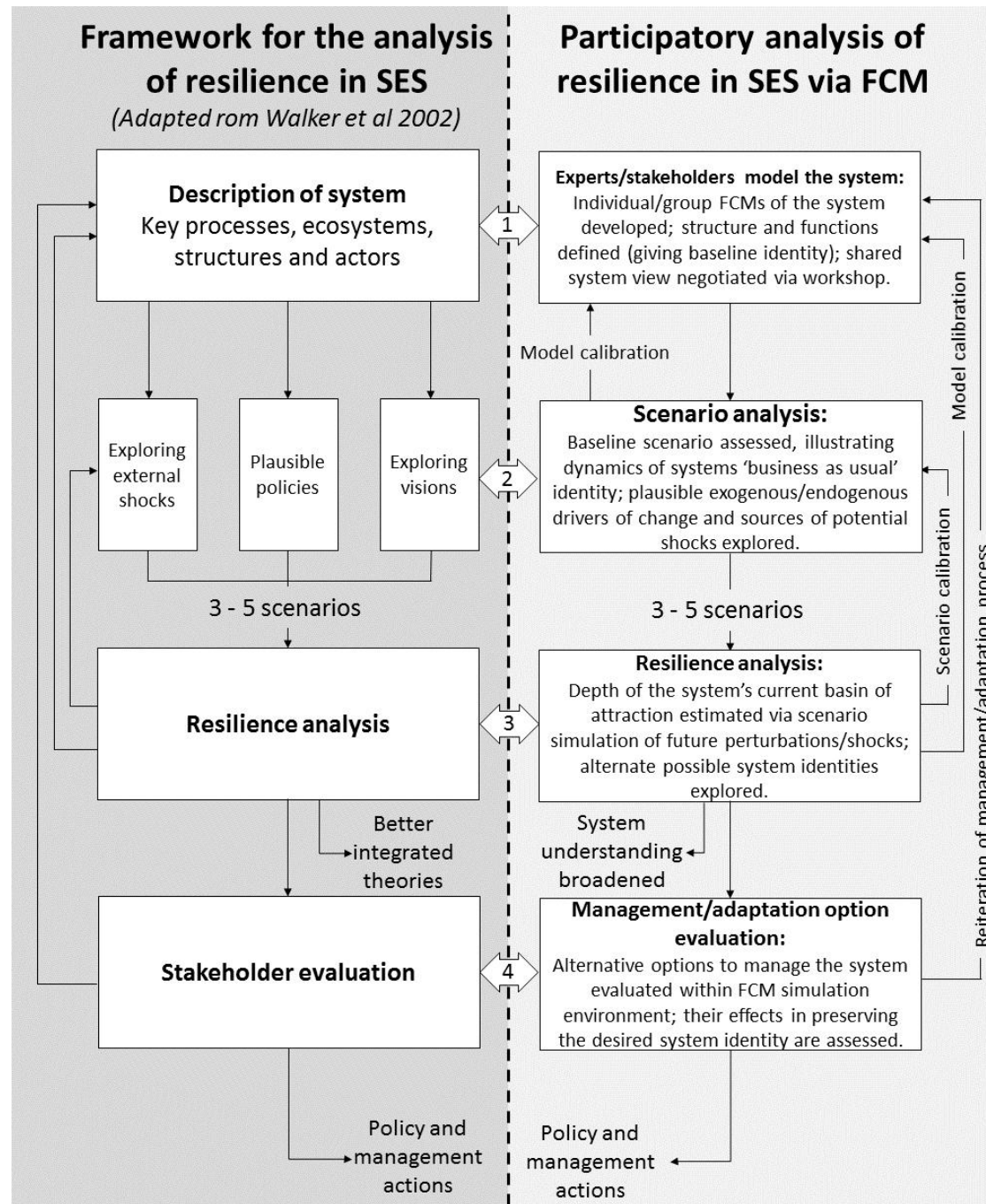


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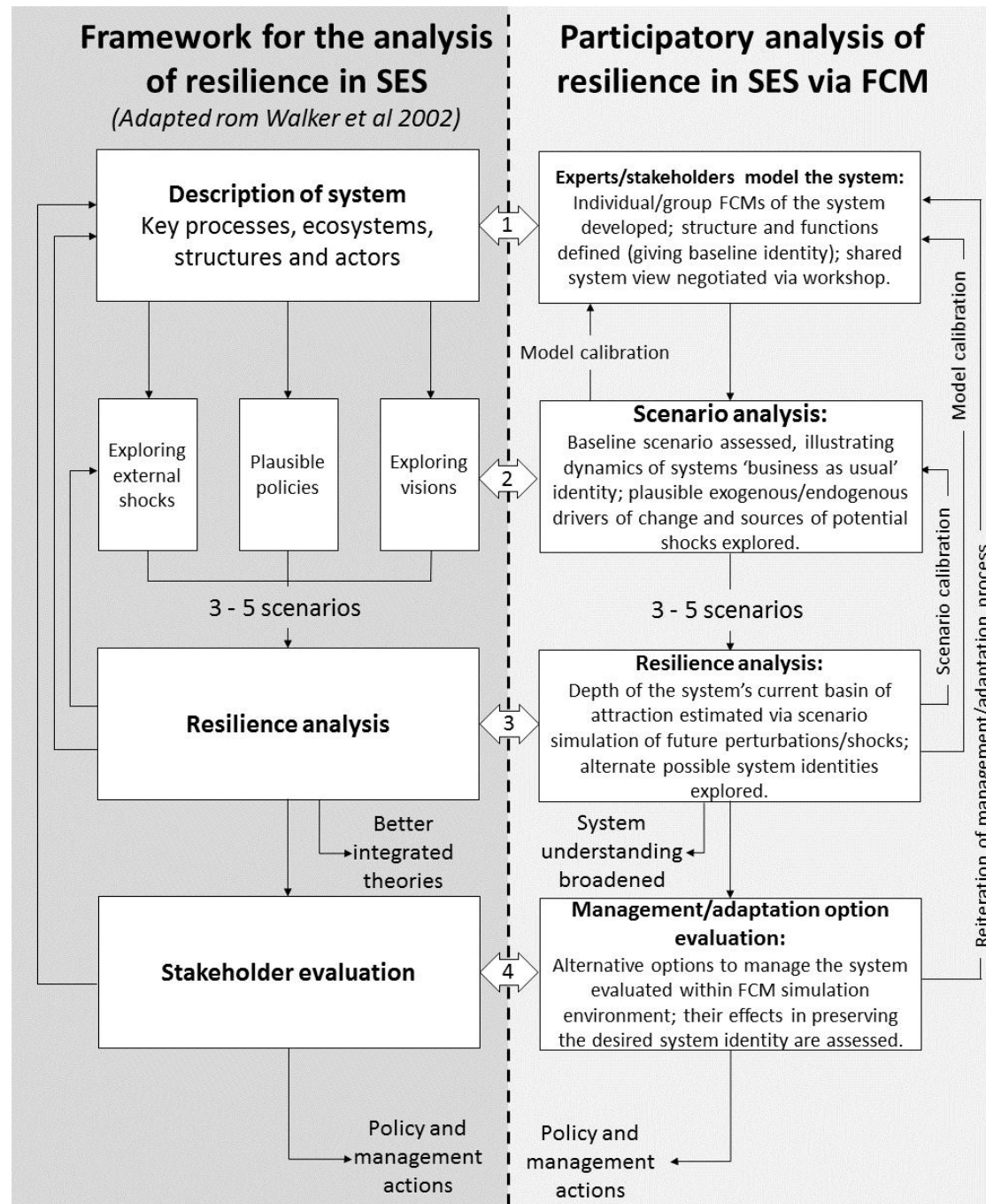
- 1. FCMs collected from individual experts or expert groups

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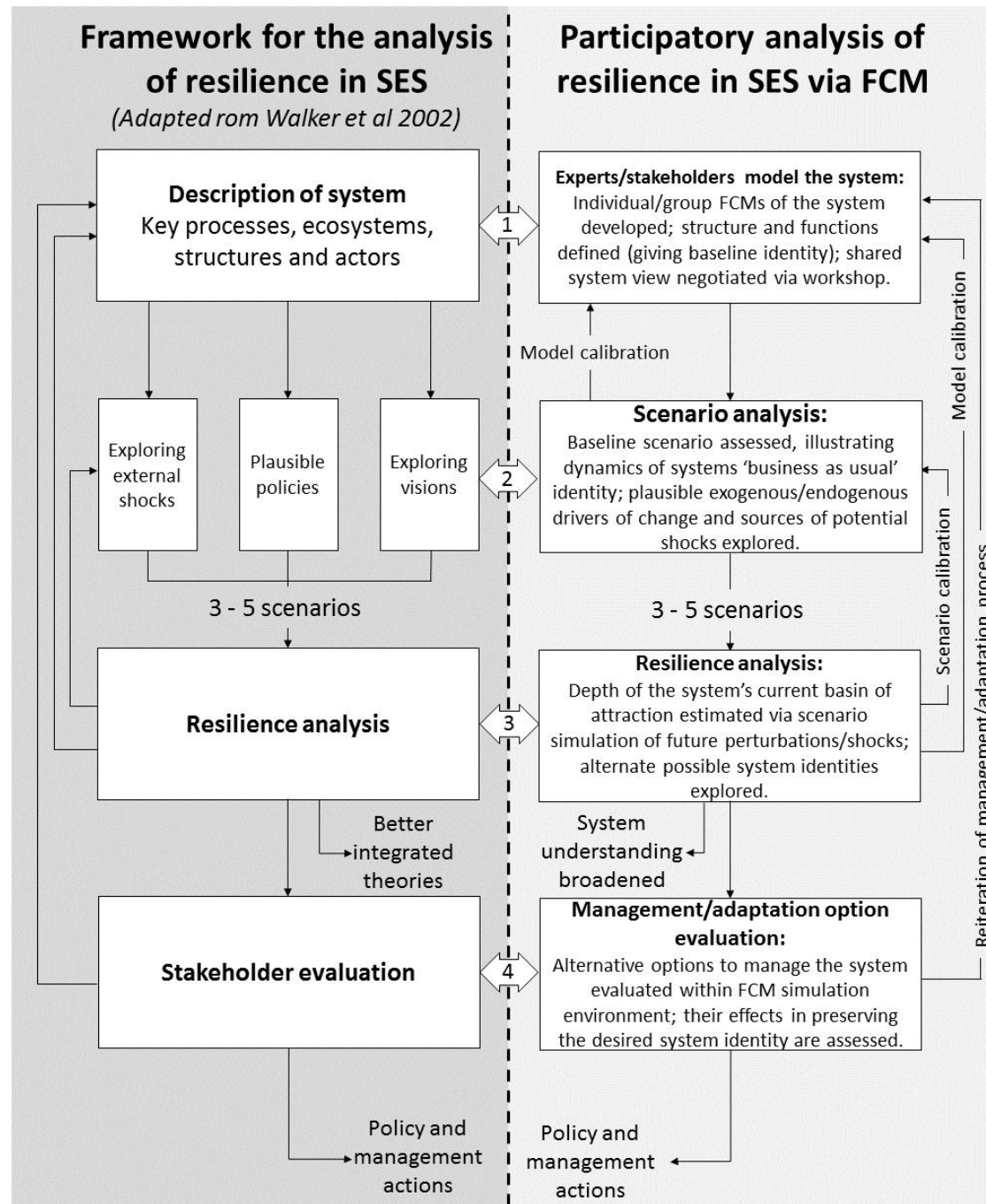
- 1. FCMs collected from individual experts or expert groups
- 2. Business-as-usual scenario indicates current basin of attraction

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- 1. FCMs collected from individual experts or expert groups
- 2. Business-as-usual scenario indicates current basin of attraction
- 3. Analyze the systems ability to maintain a preferred identity in light of 'shock'
- 4. Alternative management options to maintain system identity reviewed and compared

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## **Case Study: Bushmeat hunting in PA**

- Community-based FCM construction
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## Seeking feedback

## Case Study

*Understanding the production and consumption systems of bush meat in villages near Serengeti National Park*

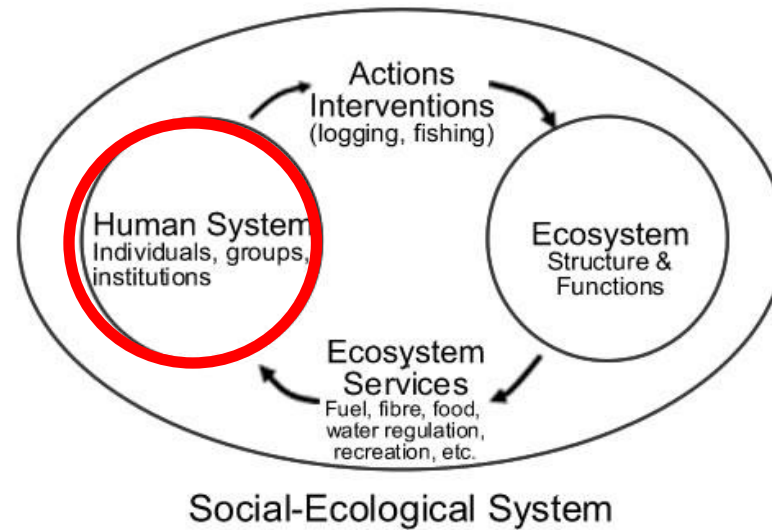


© The Africa Image Library



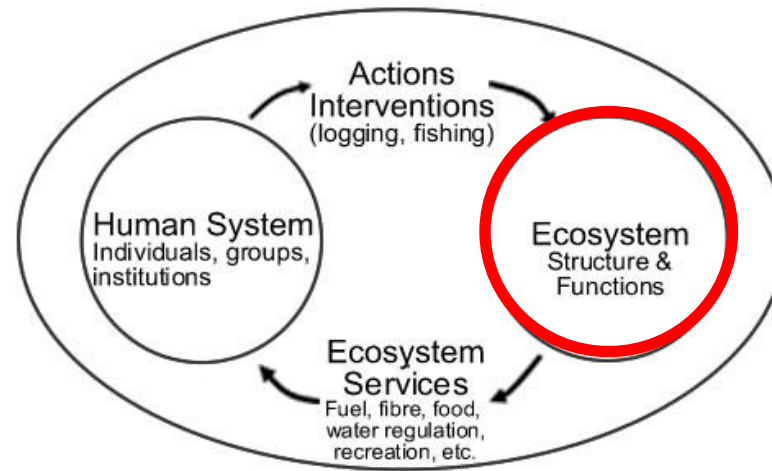
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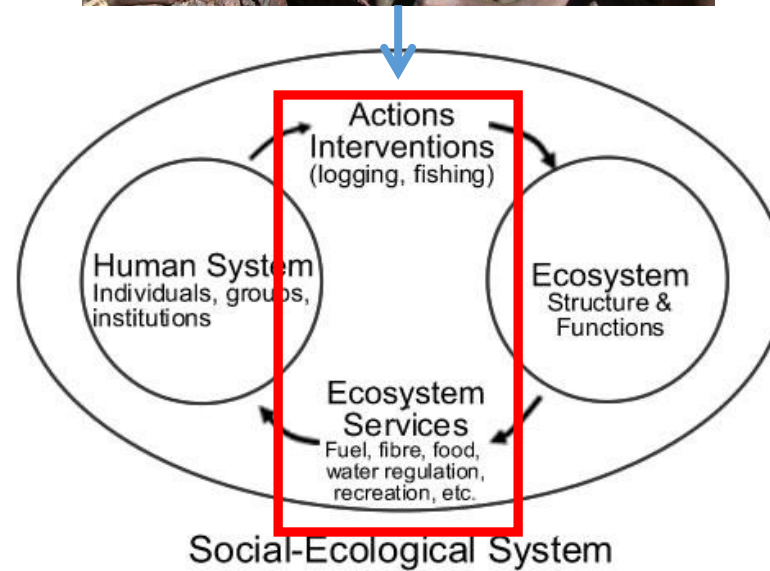


Social-Ecological System



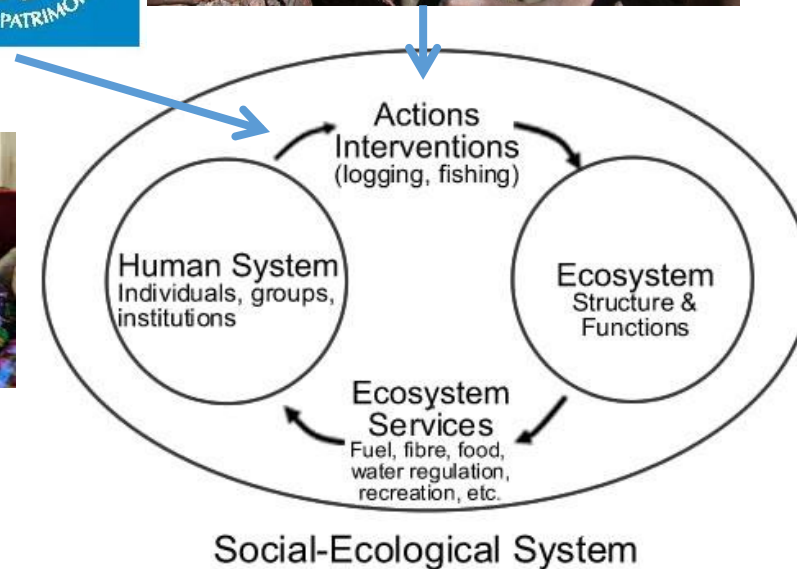
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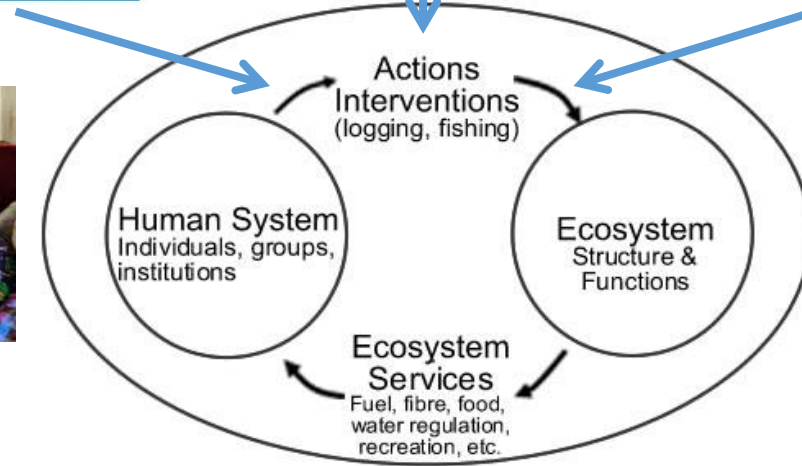
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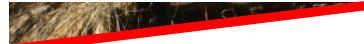


Social-Ecological System

# Case Study

*Understanding the production and consumption systems of bush meat in villages near Serengeti National Park*

How can we better understand bush meat consumption and production as a social-ecological issue and its current resilience to anticipated change?



# Workshops

11 focus groups with villages ( $N = 165$ ) comprised of former/current poachers, suppliers, bushmeat consumers

- Modeling prod and consumption system
- Mapping hunting areas
- Mapping markets
- Economic contributions
- Hunting behaviors/gear selection

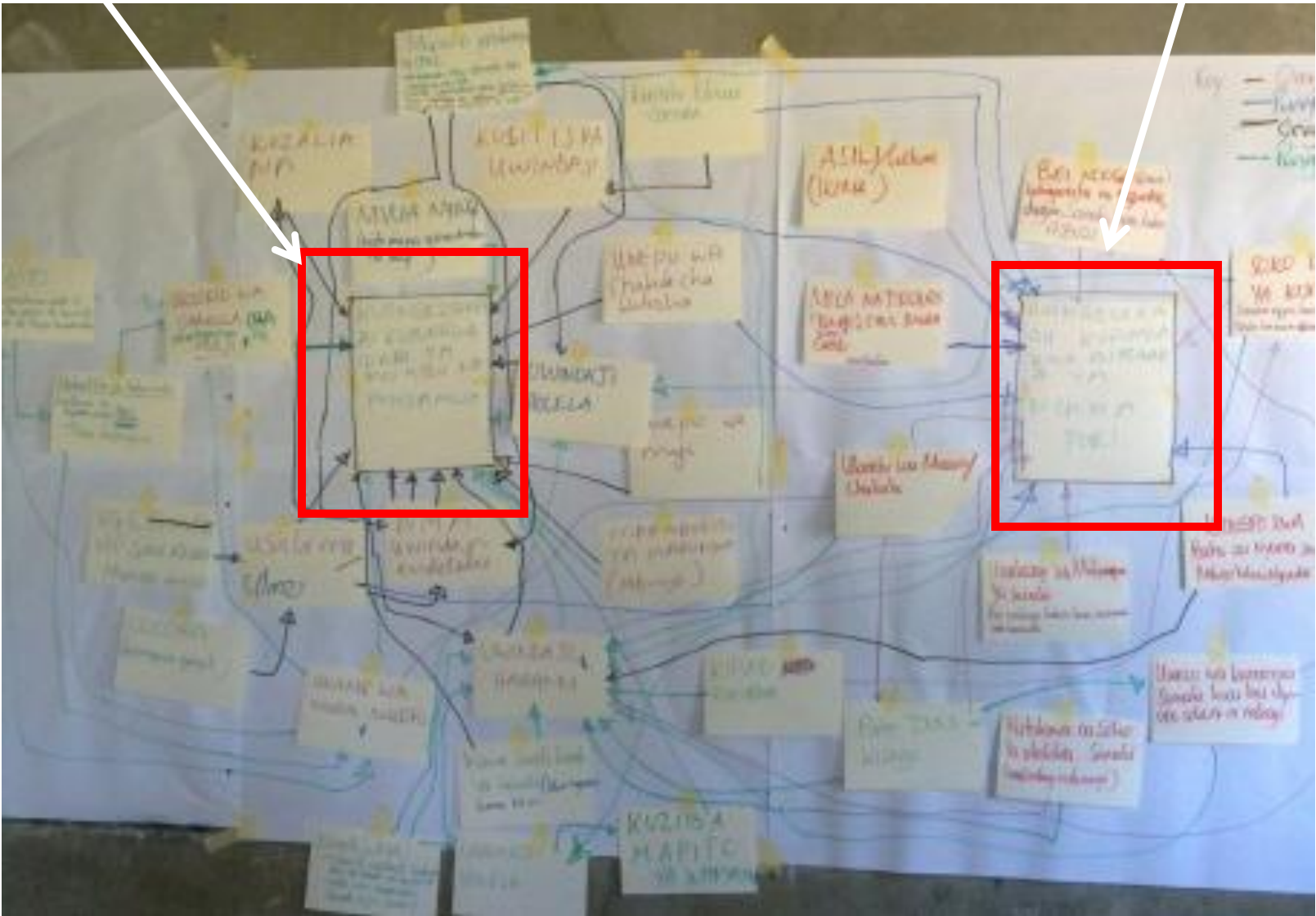






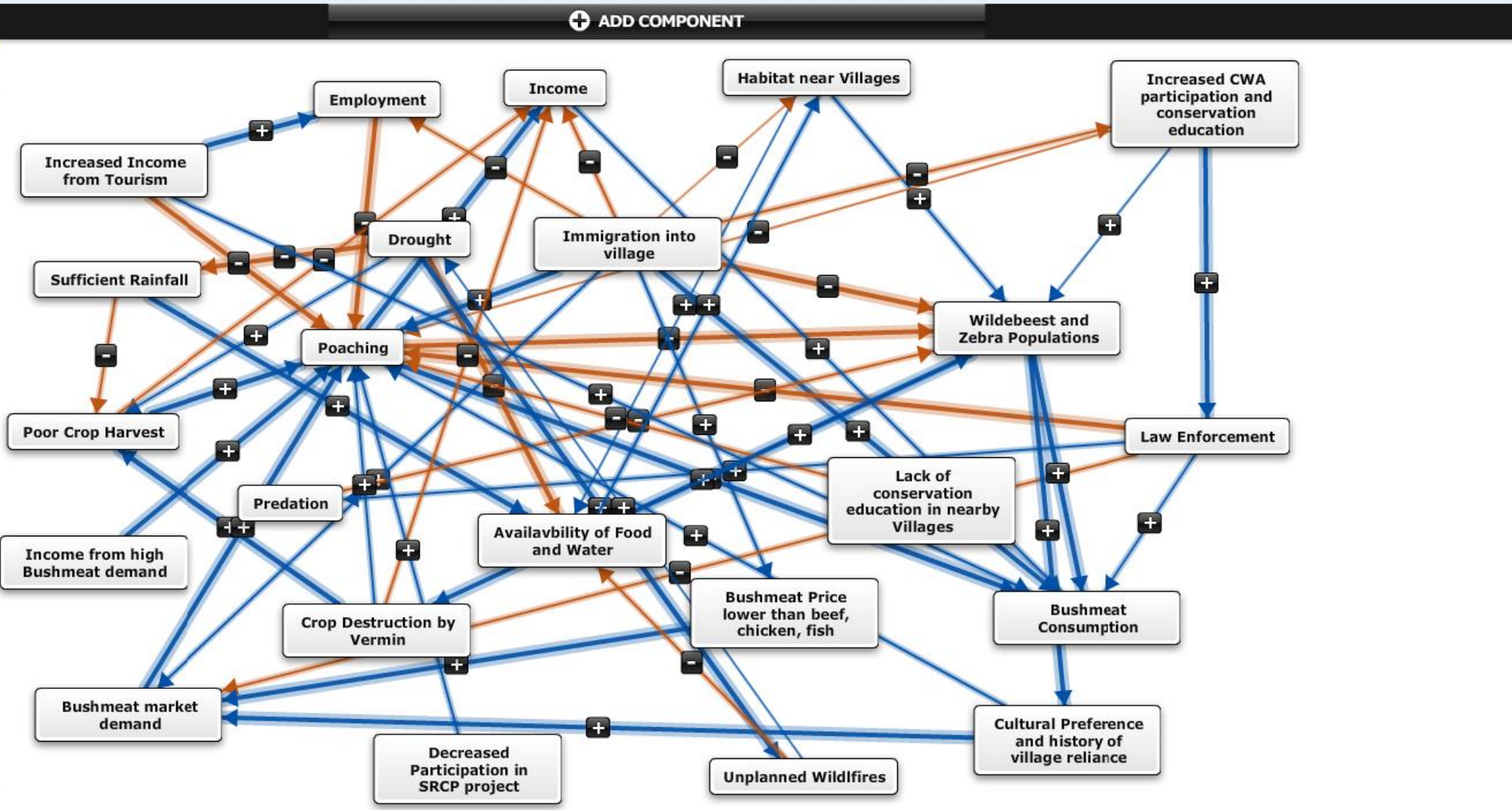
Linking ecological dynamics...

...with social dynamics

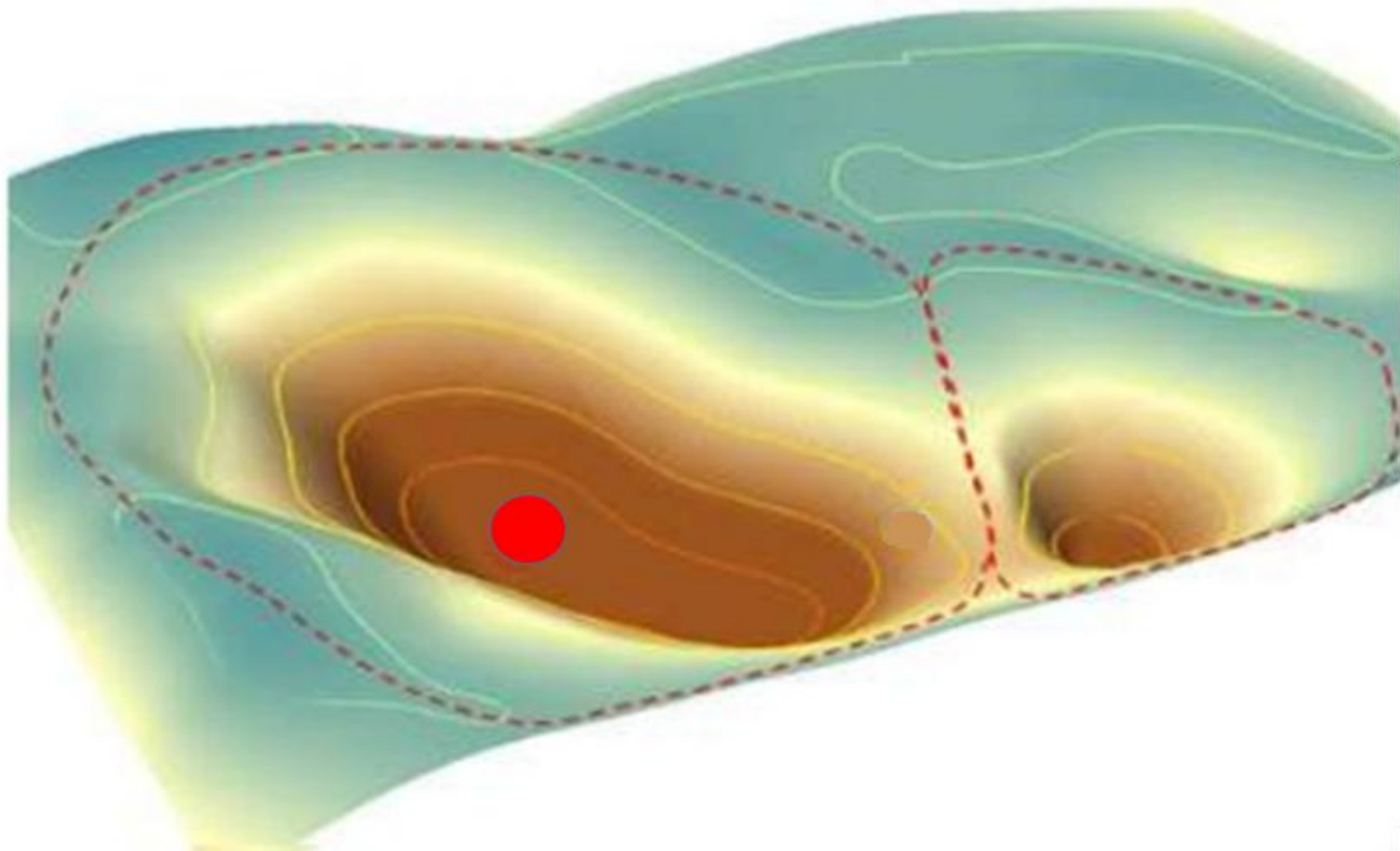


NOTES

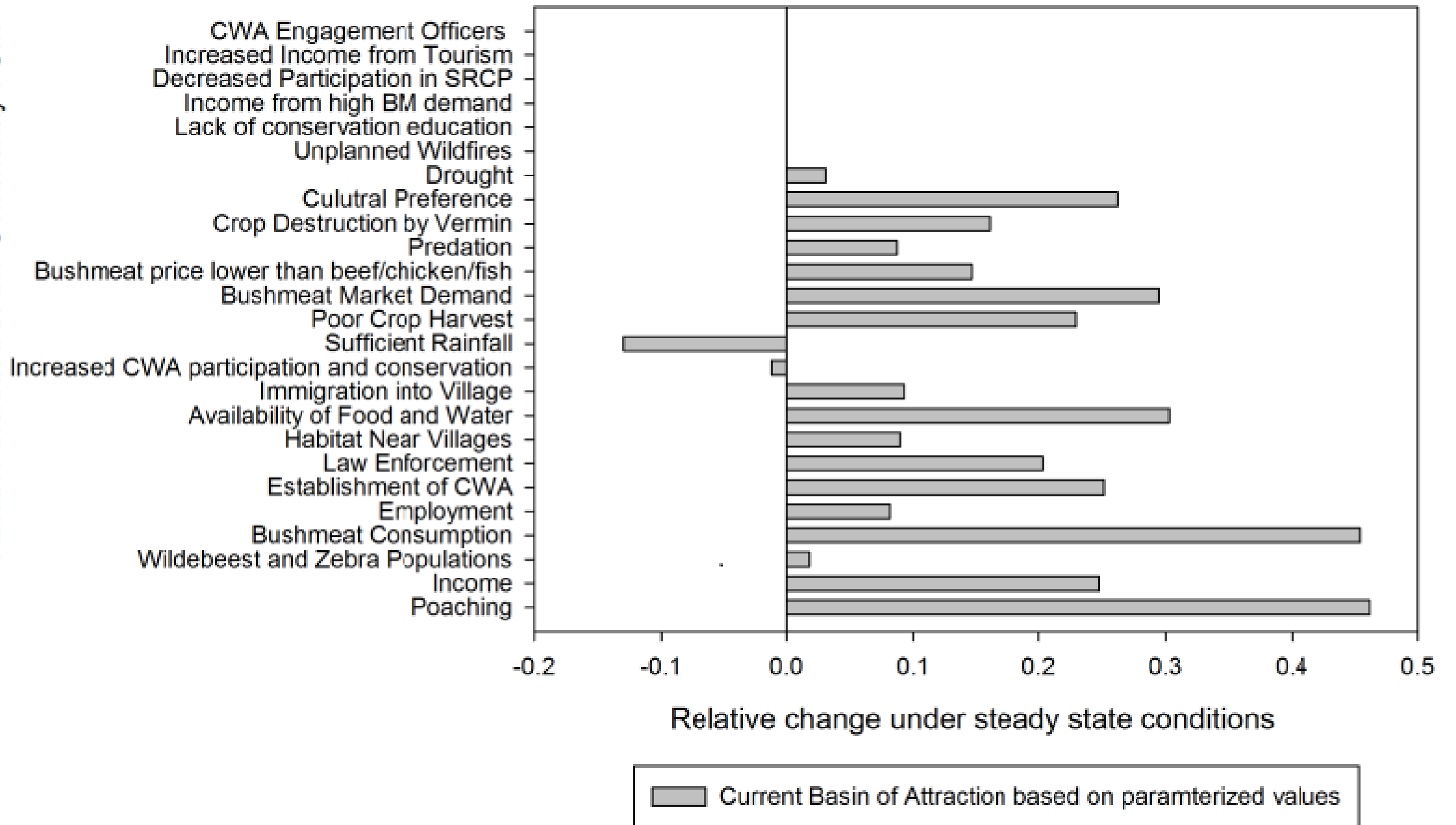
VIEW



What is the current basin of attraction?



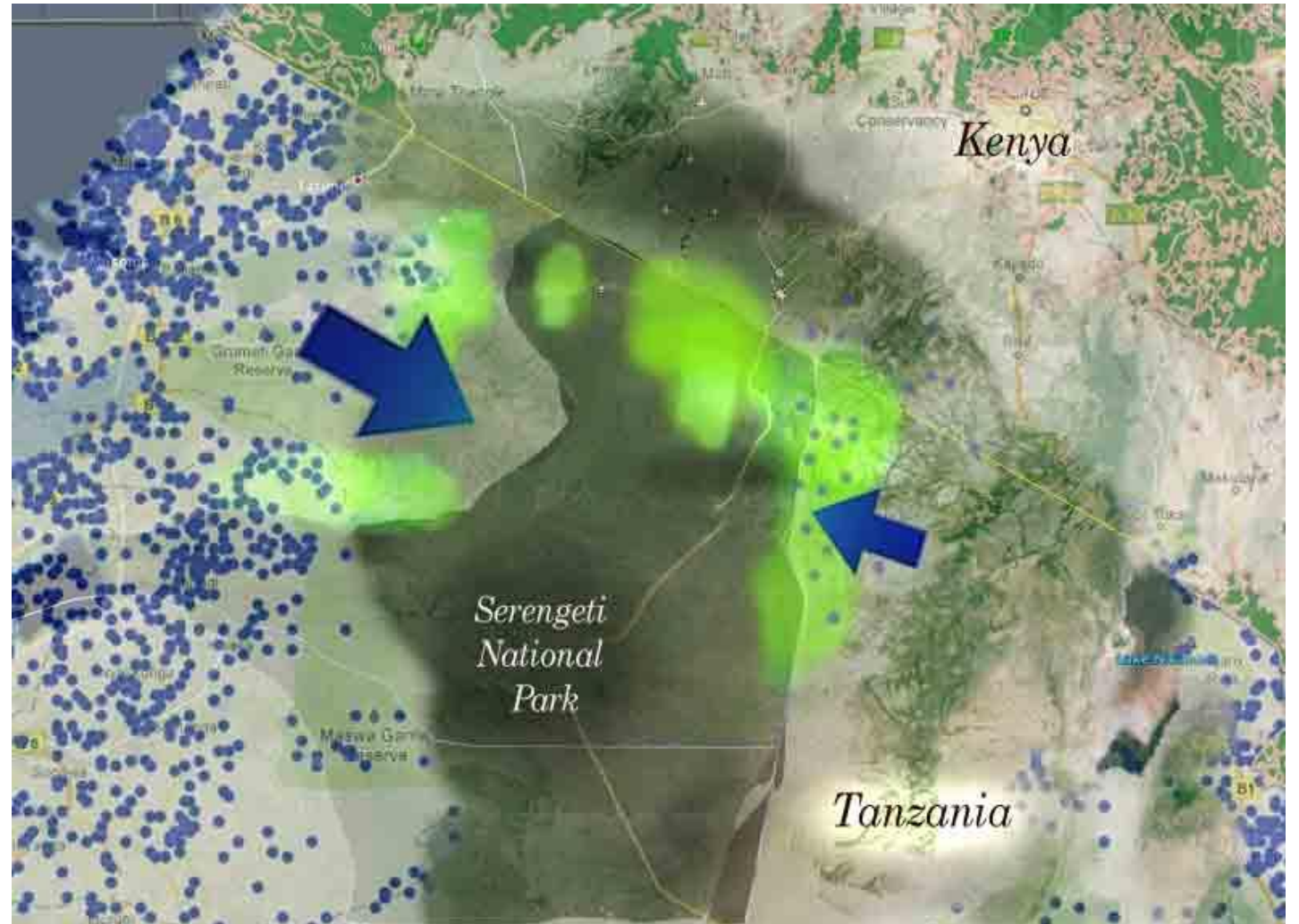
Variable included in the Community FCM



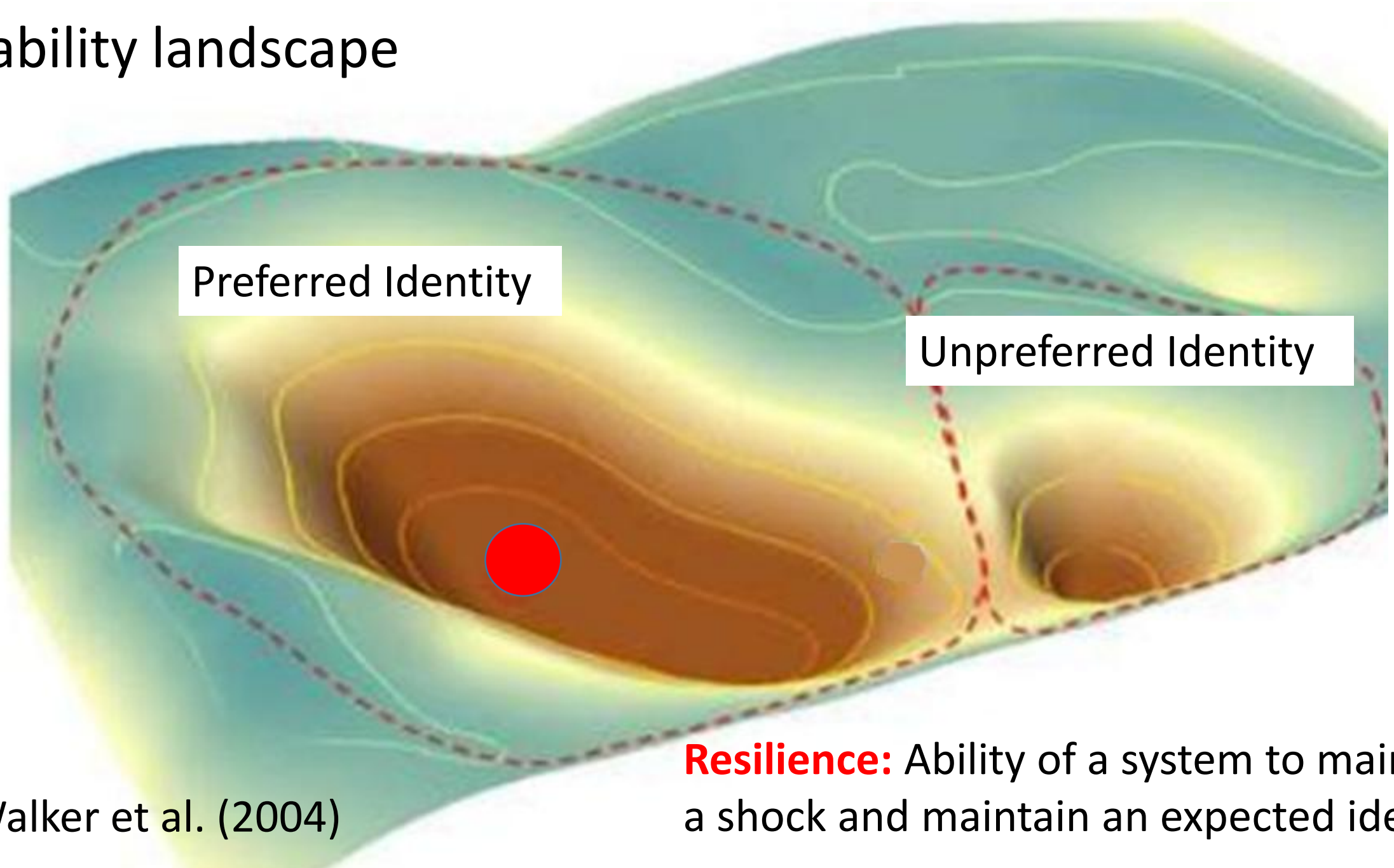
# Resilient to Perceived Shocks?

**The Shock:** Increased population near borders of protected areas.

Approximately 2 million people live along the western edge of the SNP (Kideghesho 2010), and the populations in these villages are increasing by approximately 3% per year (Loibooki et al. 2002; Kideghesho 2010).



# Stability landscape



Walker et al. (2004)

**Resilience:** Ability of a system to maintain a shock and maintain an expected identity

# Strategies to deal with shocks?

- Management Option 1: Establishment of Community Wildlife Area
- Management Option 2: Hiring Community Engagement Officers

+ ADD COMPONENT

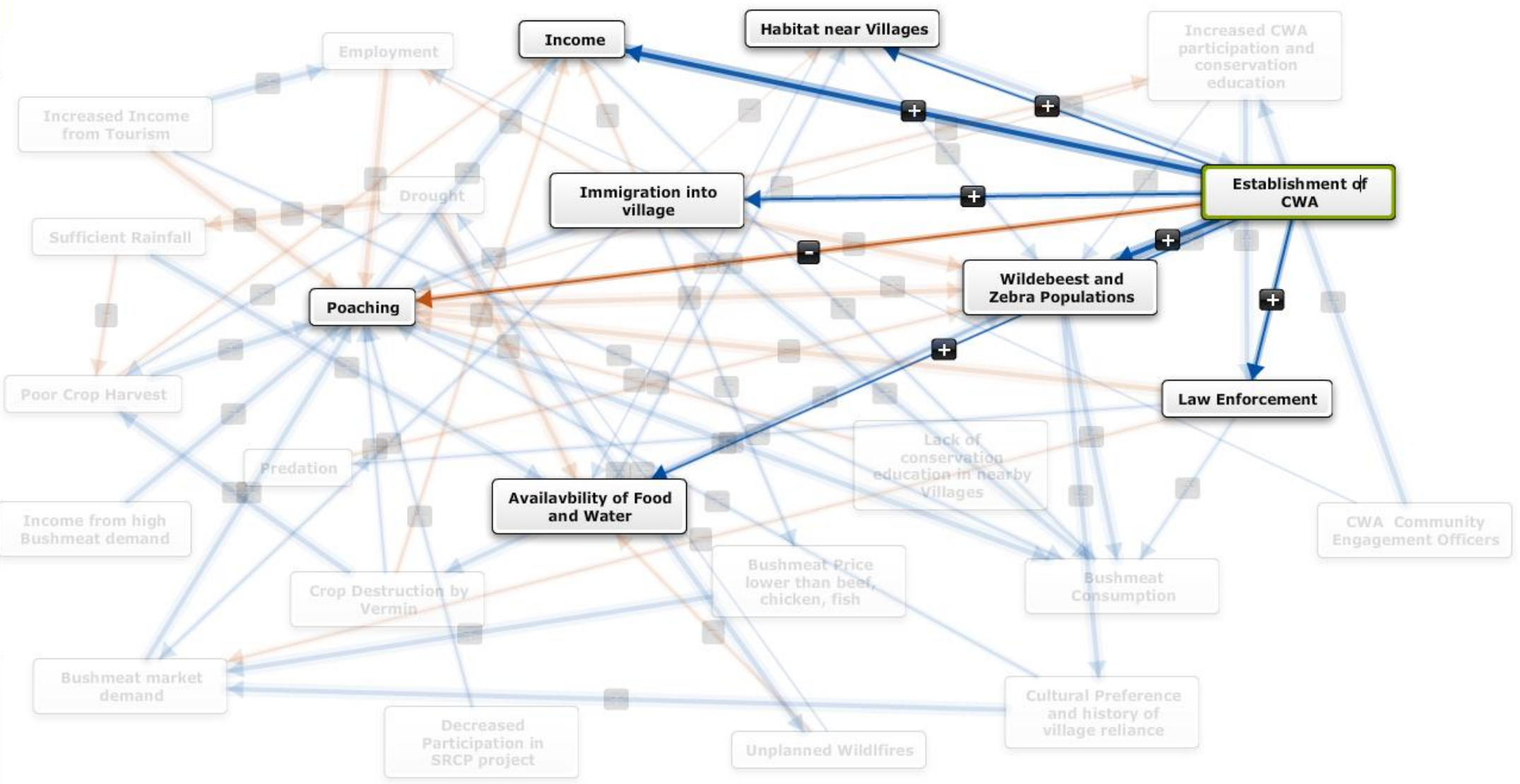
Establishment of CWA

NOTES

Enter notes

VIEW

- View Only Lines From
- View Only Lines To



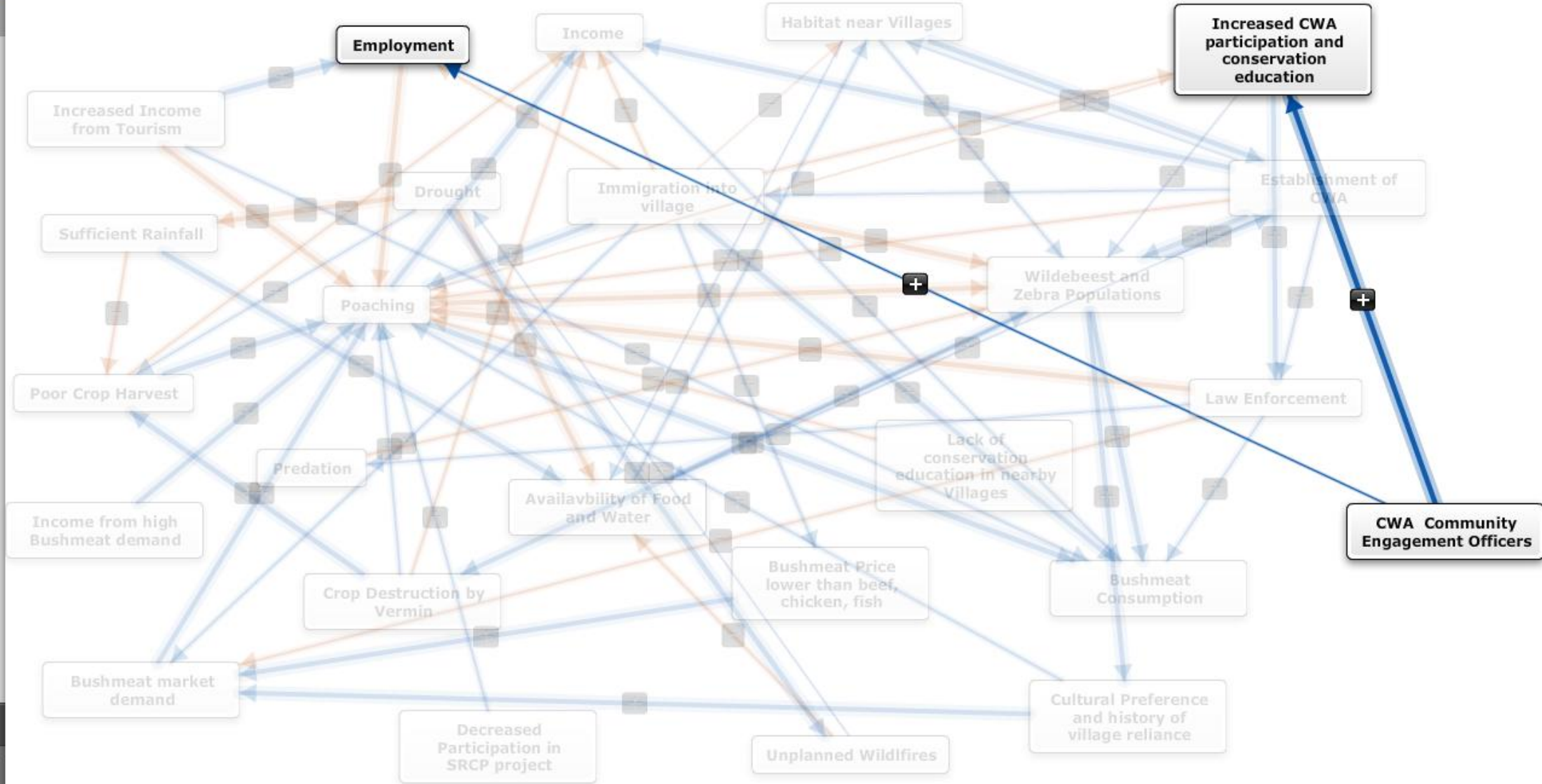


ADD COMPONENT

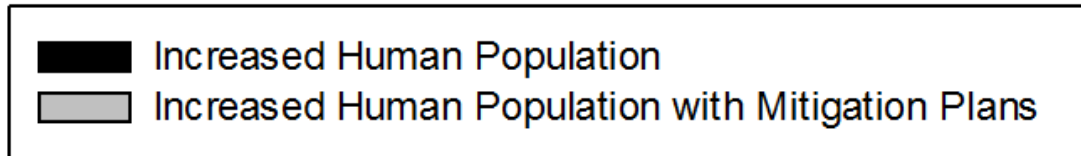
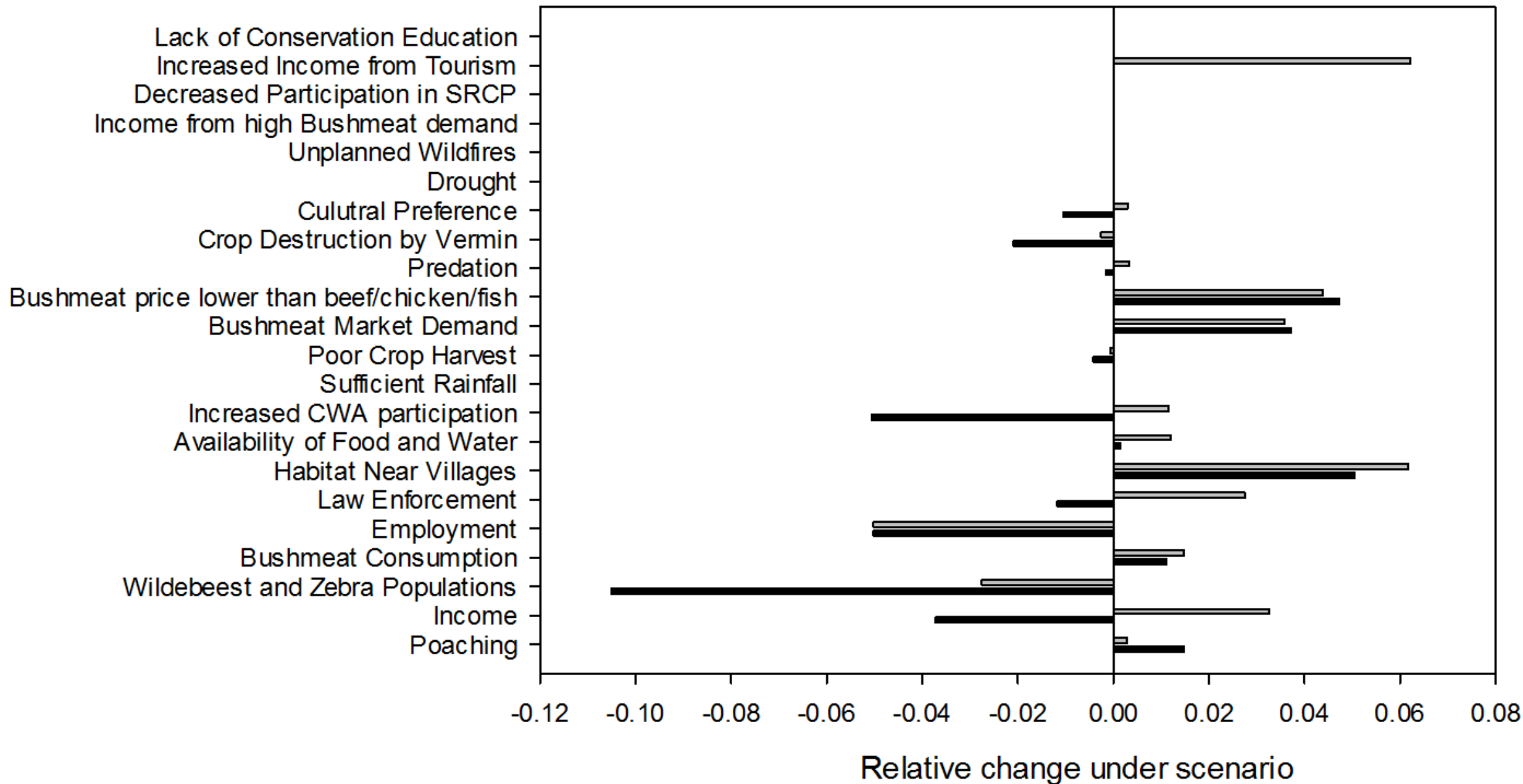
NOTES

VIEW

Reset View Filter



Variable included in Community FCM



# Preference for SES states: Defining Values

Component included in the community model	Desired Change
Lack of conservation education	Decrease
Decreased participation in a local microcredit lending program	Decrease
Unplanned wildfires	Decrease
Drought	Decrease
Crop destruction by vermin	Decrease
Poor crop harvest	Decrease
Poaching	Decrease
Income from tourism	Increase
Sufficient rainfall	Increase
Increased community wildlife management participation	Increase
Availability of food and water	Increase
Habitat near villages	Increase
Employment	Increase
Wildebeest and zebra populations	Increase
Income	Increase
Bushmeat price lower than beef/chicken/fish	Neutral
Cultural preference	Neutral
Predation	Neutral
Bushmeat market demand	Neutral
Law enforcement	Neutral
Bushmeat consumption	Neutral
Income from bushmeat demand	Neutral

# Preference for SES states: Under Shocks?

Component included in the community model	Desired Change	Scenario: Increased population
Lack of conservation education	Decrease	0
Decreased participation in a local microcredit lending program	Decrease	0
Unplanned wildfires	Decrease	0
Drought	Decrease	0
Crop destruction by vermin	Decrease	-0.02087
Poor crop harvest	Decrease	-0.00413
Poaching	Decrease	0.01487
Income from tourism	Increase	0
Sufficient rainfall	Increase	0
Increased community wildlife management participation	Increase	-0.05059
Availability of food and water	Increase	0.00159
Habitat near villages	Increase	0.05055
Employment	Increase	-0.05022
Wildebeest and zebra populations	Increase	-0.10509
Income	Increase	-0.03719
Bushmeat price lower than beef/chicken/fish	Neutral	0.04727
Cultural preference	Neutral	-0.01055
Predation	Neutral	-0.00140
Bushmeat market demand	Neutral	0.03724
Law enforcement	Neutral	-0.01170
Bushmeat consumption	Neutral	0.01112
Income from bushmeat demand	Neutral	0

# Preference for SES states: with mgt in place...

Component included in the community model	Desired Change	Scenario: Increased population	Scenario: Increased population plus mitigation	Desired Change Achieved (Yes = 1, No = 0)
Lack of conservation education	Decrease	0	-0.06175	1
Decreased participation in a local microcredit lending program	Decrease	0	0	0
Unplanned wildfires	Decrease	0	0	0
Drought	Decrease	0	0	0
Crop destruction by vermin	Decrease	-0.02087	-0.00259	1
Poor crop harvest	Decrease	-0.00413	-0.00066	1
Poaching	Decrease	0.01487	-0.00066	1
Income from tourism	Increase	0	0.06218	1
Sufficient rainfall	Increase	0	0	0
Increased community wildlife management participation	Increase	-0.05059	0.01158	1
Availability of food and water	Increase	0.00159	0.01195	1
Habitat near villages	Increase	0.05055	0.06175	1
Employment	Increase	-0.05022	-0.05022	0
Wildebeest and zebra populations	Increase	-0.10509	-0.02756	1
Income	Increase	-0.03719	0.03264	1
Bushmeat price lower than beef/chicken/fish	Neutral	0.04727	0.04389	-
Cultural preference	Neutral	-0.01055	0.00303	-
Predation	Neutral	-0.00140	0.00335	-
Bushmeat market demand	Neutral	0.03724	0.03585	-
Law enforcement	Neutral	-0.01170	0.02750	-
Bushmeat consumption	Neutral	0.01112	0.01487	-
Income from bushmeat demand	Neutral	0	0	-

# Conclusions

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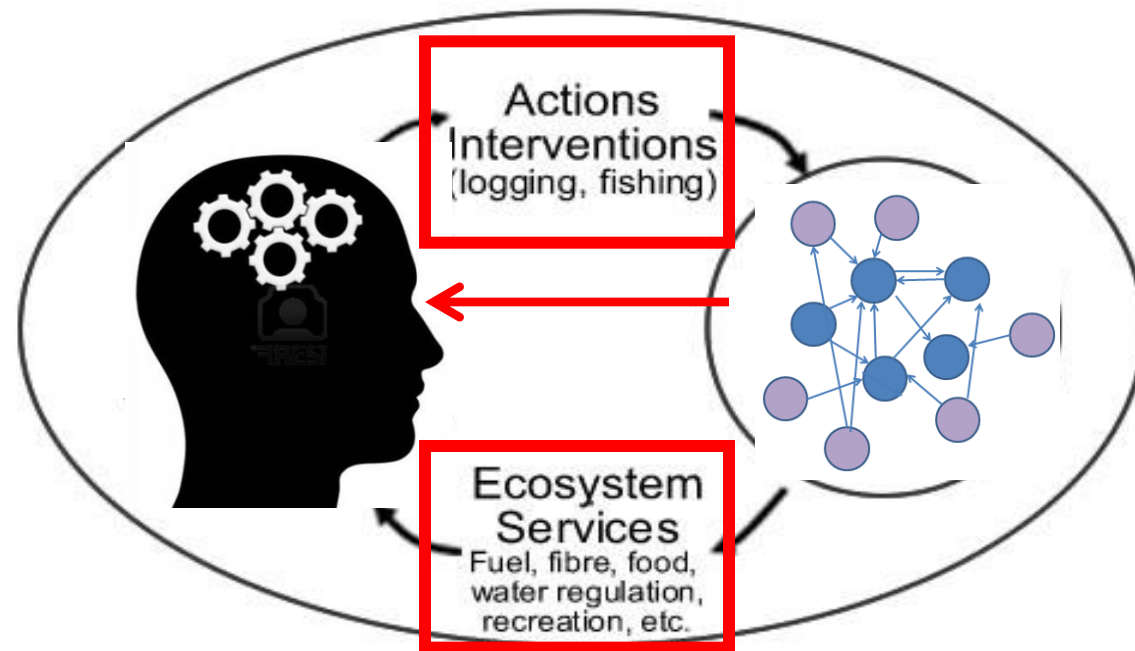
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# Conclusions

- FCM may operationalize participatory resilience analyses promoted in the literature (Walker et al. 2002)
- FCM allows comparisons of perceived basins of attraction and changes in stable states under community defined shocks
- However, questions remain about whether thresholds are crossed and changes in the system under scenarios constitute identity changes and shifts into new basins of attraction
- Ultimately, FCM do provide a method to for communities to define current perceived dynamics and discuss valued and preferred stable states

Thanks for listening  
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Social-Ecological System