Ecosystem services and hotspot distribution under four different land-use scenarios in Massachusetts, USA

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QUESTION

How do different land-use trajectories affect the distribution of ecosystem service hotspots within the state of Massachusetts?

STAKEHOLDER DEFINED SCENARIOS

In 2014 researchers at the Harvard Forest collaborated with a group of stakeholders to develop and simulate four different land-use scenarios for the state of Massachusetts that depicted different rates, intensities, and distributions of housing development, timber harvest, and land protection, over the next 50 years (Thompson et al., 2014). The scenarios are:

RECENT TRENDS - Linear continuation of recent trends in conservation, development, agriculture, and timber harvest.

OPPORTUNISTIC GROWTH - High rate of sprawling development with frequent and intensive harvests in the first two decades.

REGIONAL SELF-RELIANCE - Increasing timber harvest and forest conversion to agriculture.

FOREST AS INFRASTRUCTURE - Clustered development and steady increase of timber harvest. Emphasis on forests as renewable resources.

ECOSYSTEM SERVICES

Ecosystem services are benefits people obtain from nature that can provide us with necessities such as fresh water, food and fuel.

Ecosystem services abundance and distribution can be affected by land-use.

Using 50-m resolution maps from the Massachusetts Stakeholder scenarios project, we assessed land-use impacts on the state's capacity to provision the following services:
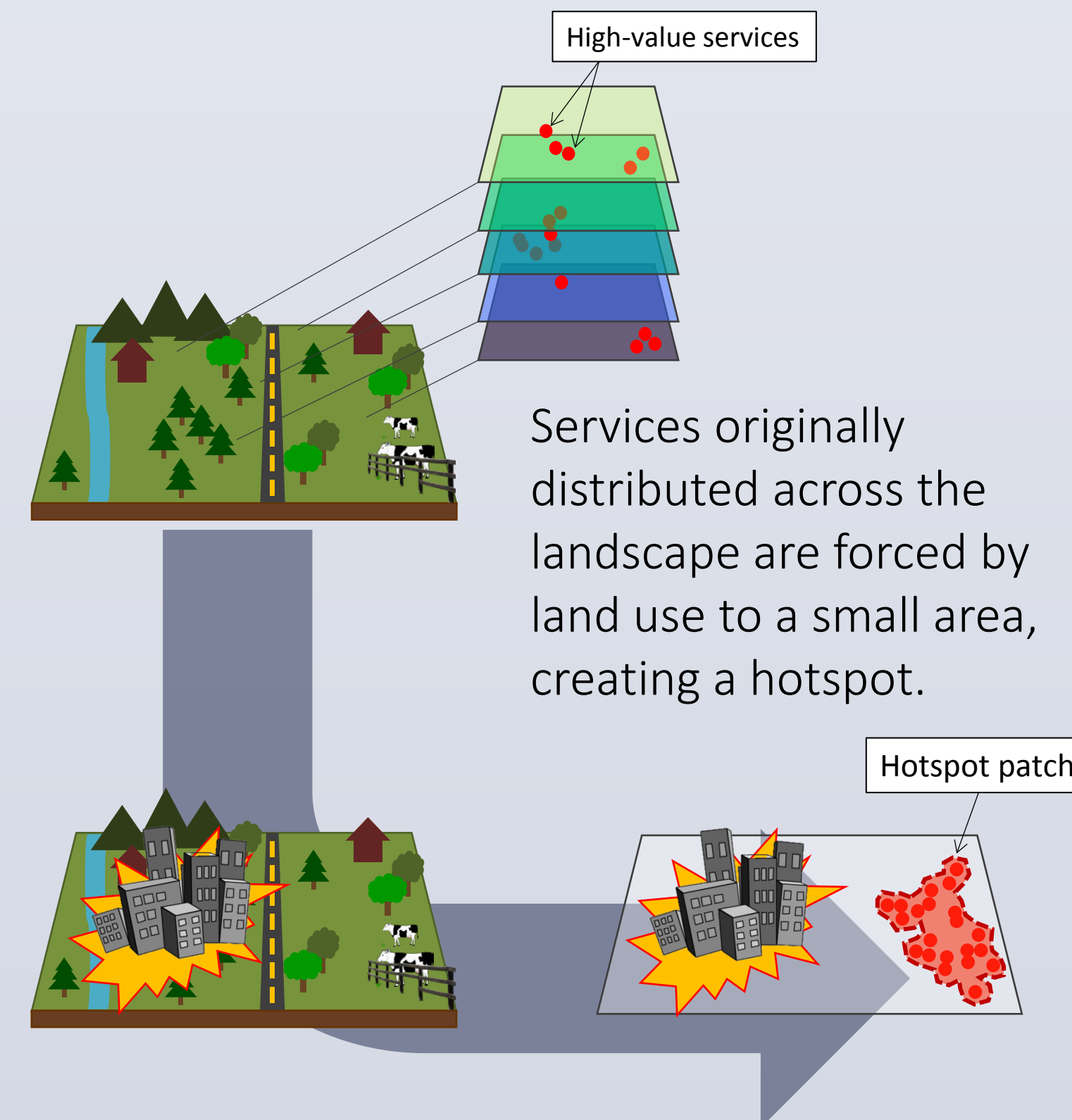
- Habitat quality
- Carbon storage
- Nitrogen retention
- Phosphorus retention
- Pervious surface
- Harvest
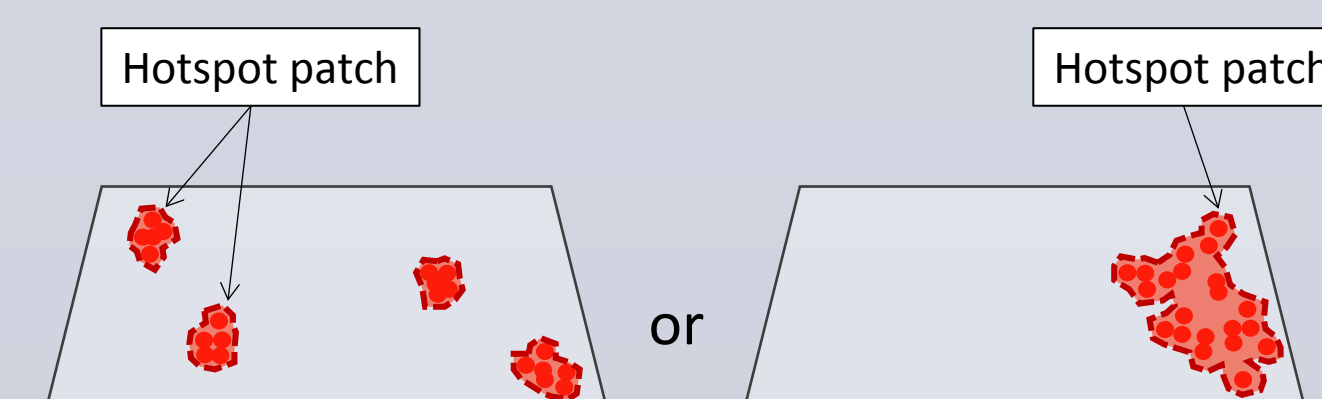- Agriculture
- Water retention

HOTSPOTS

The provisioning of ecosystem services is spatially heterogeneous. We identified areas with a high-value service as those sites that were in the top 20th percentile of all sites. Furthermore, sites that provided 5 or more high-value ecosystem services were identified as an ecosystem service hotspot.

High Value: Water

High Value: Carbon

High Value: Agriculture
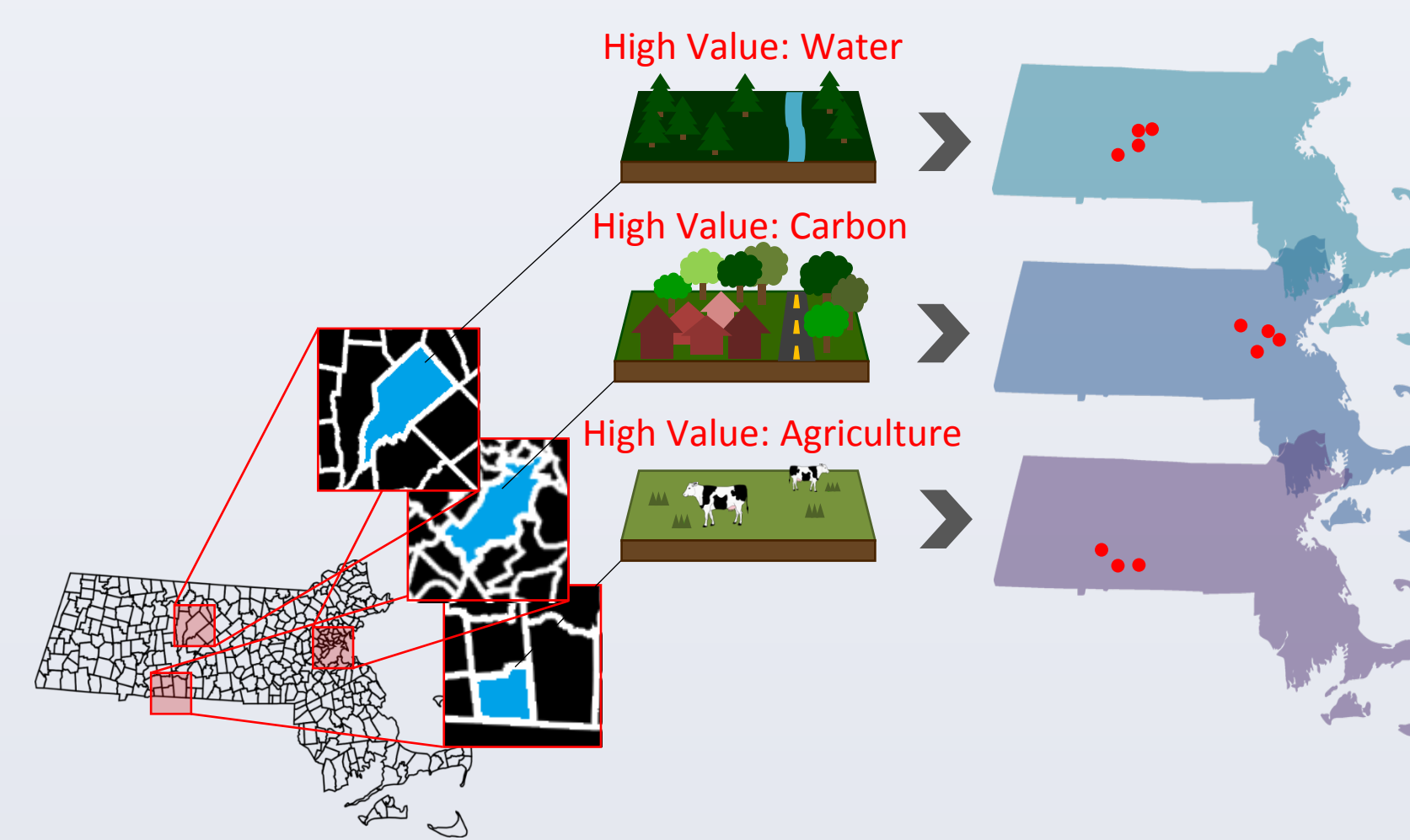
Land use affects hotspot abundance and distribution across the landscape.

High-value services

Services originally distributed across the landscape are forced by land use to a small area, creating a hotspot.

Hotspot patch

Hotspots can appear in big patches or distributed across the landscape in smaller fragments.

Hotspot patch   or   Hotspot patch

RESULTS

Hotspot analysis: State level

Year 0   Year 50

(a) Recent Trends

(b) Opportunistic Growth

(c) Regional Self-Reliance

(d) Forest as Infrastructure

No High-Value
Warm Spots
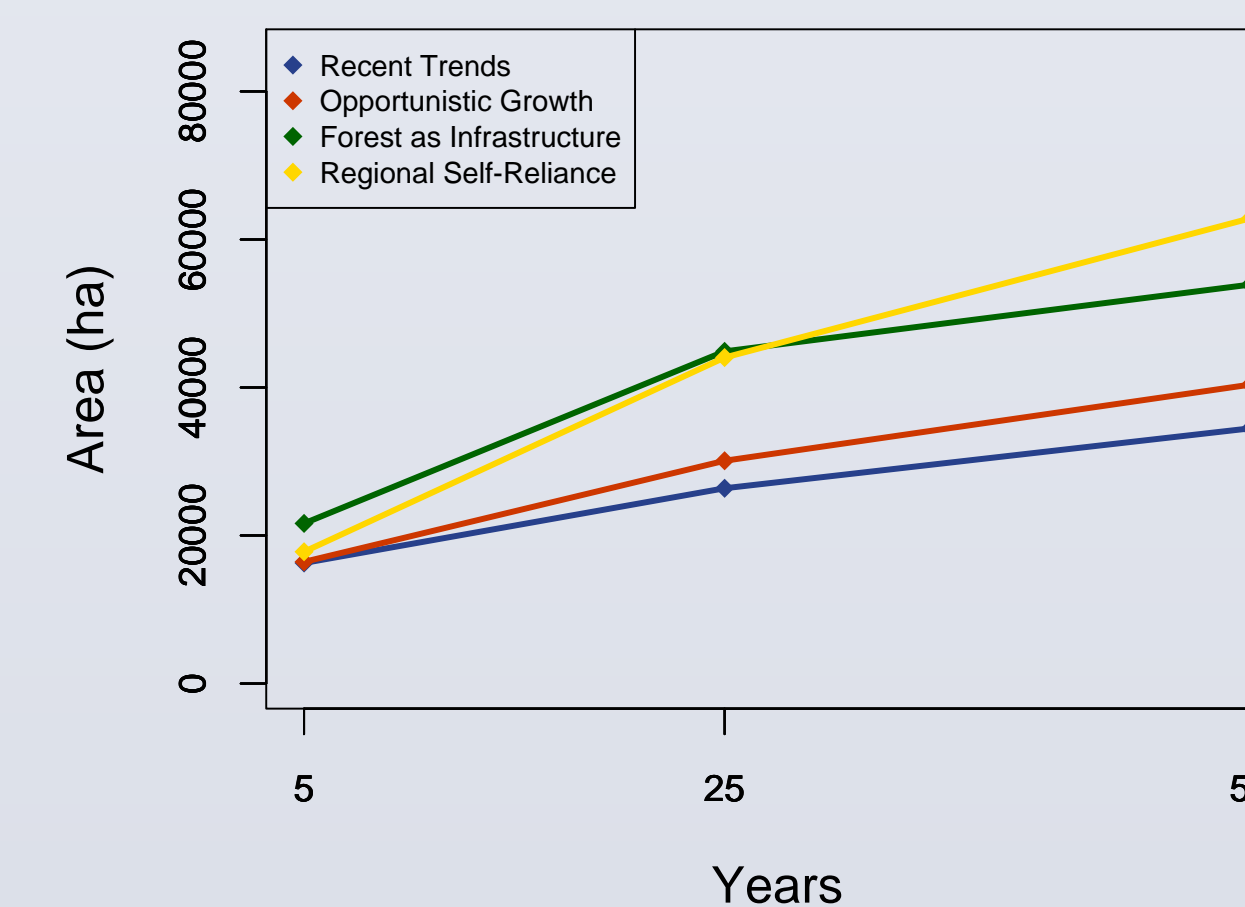Hotspots

0 15 30 60 90 120
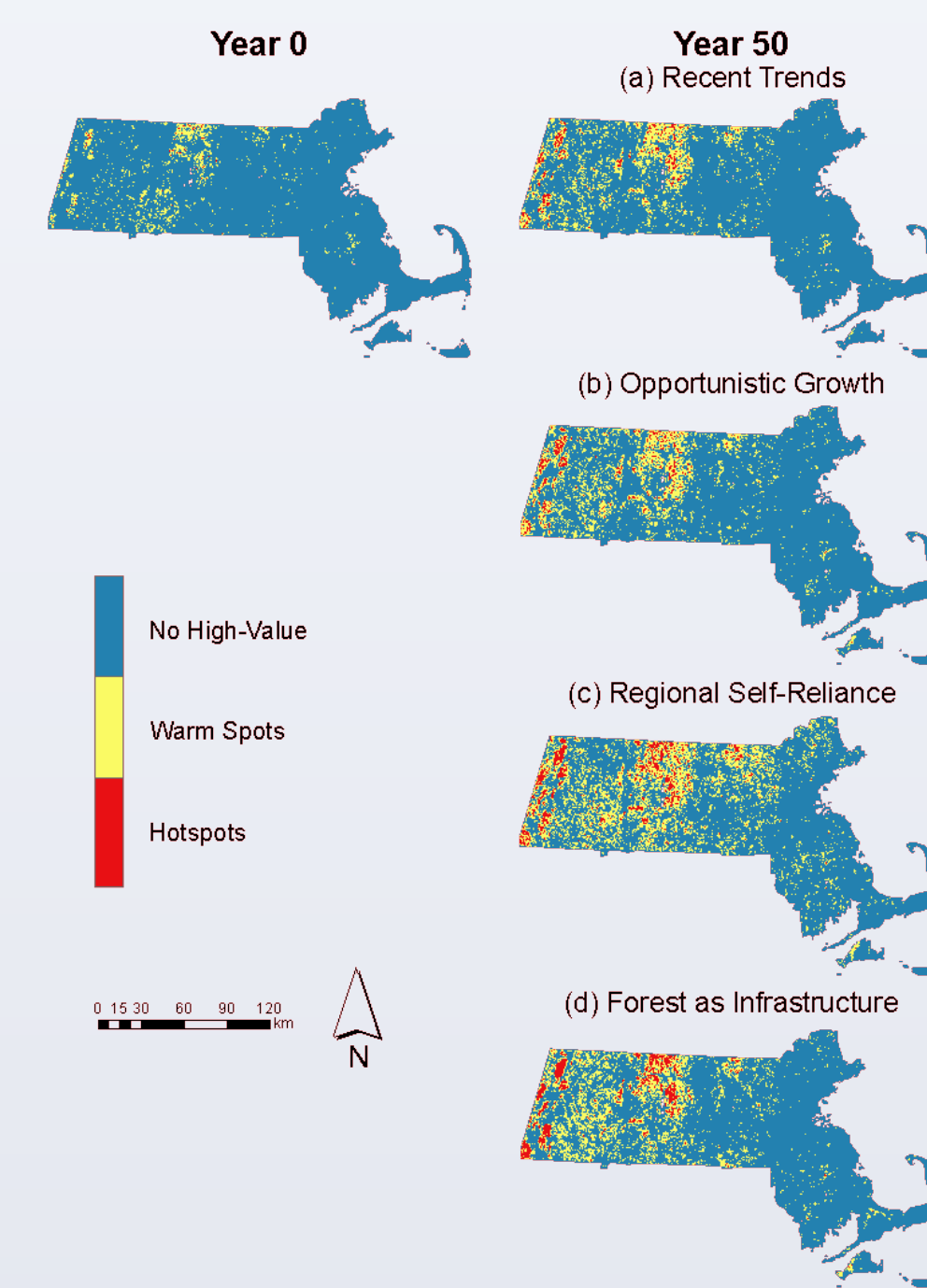
- Blue areas show places with no high-value services, in yellow are warm spots with less than 5 high-value services, red areas represent hotspots.
- *Regional Self-Reliance* has the highest amount of hotspots after 50 years.

Hotspot Area: State Level

Recent Trends
Opportunistic Growth
Forest as Infrastructure
Regional Self-Reliance

Area (ha) — Years: 5, 25, 50

- *Recent Trends* – smallest increase of hotspot area
- *Regional Self-Reliance* – greatest increase of hotspot area

**High-value Ecosystem Services Fate Through Time**

Recent Trends

Number of high-value services — years: 5, 50

20% 10% 5% 1%

- *Recent Trends* – greatest percentage without change
- *Opportunistic Growth* – greatest loss of high-value areas
- *Regional Self-Reliance* – greatest increase of high-value areas
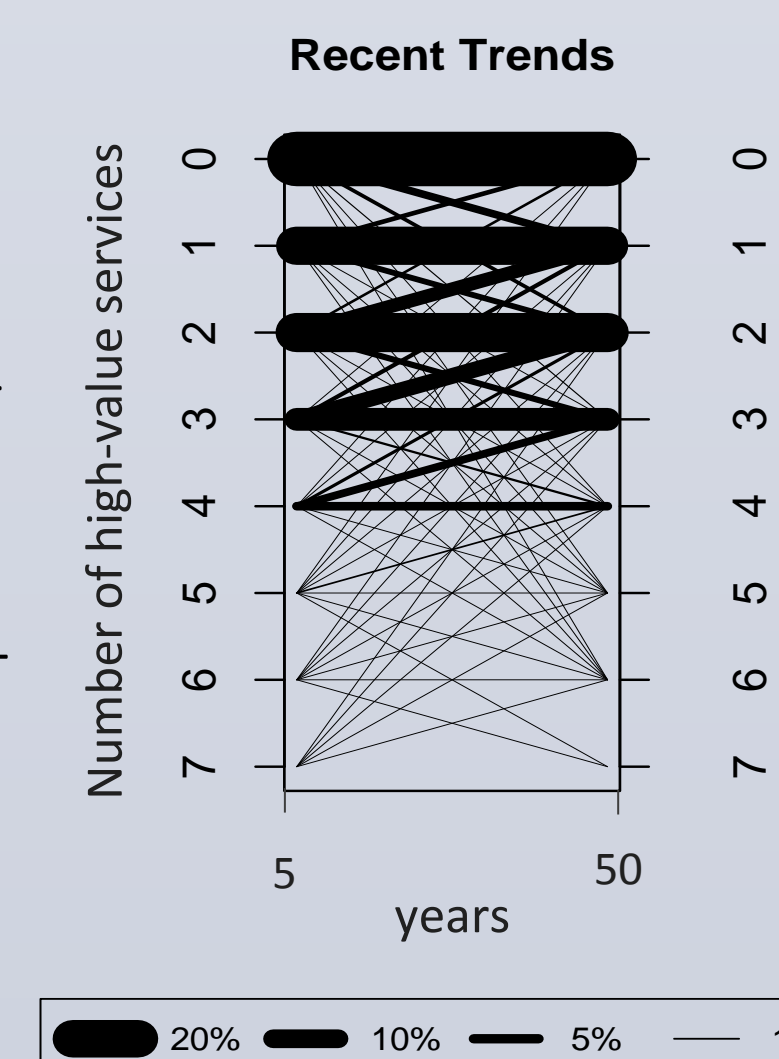
In all scenarios, average hotspot size increased through time, which reflects the concentration of services and, in some cases, the expansion of timber and agriculture.

Hotspot Mean Patch Size: State Level

Recent Trends
Opportunistic Growth
Forest as Infrastructure
Regional Self-Reliance

Patch Size (m2) — Years: 5, 25, 50
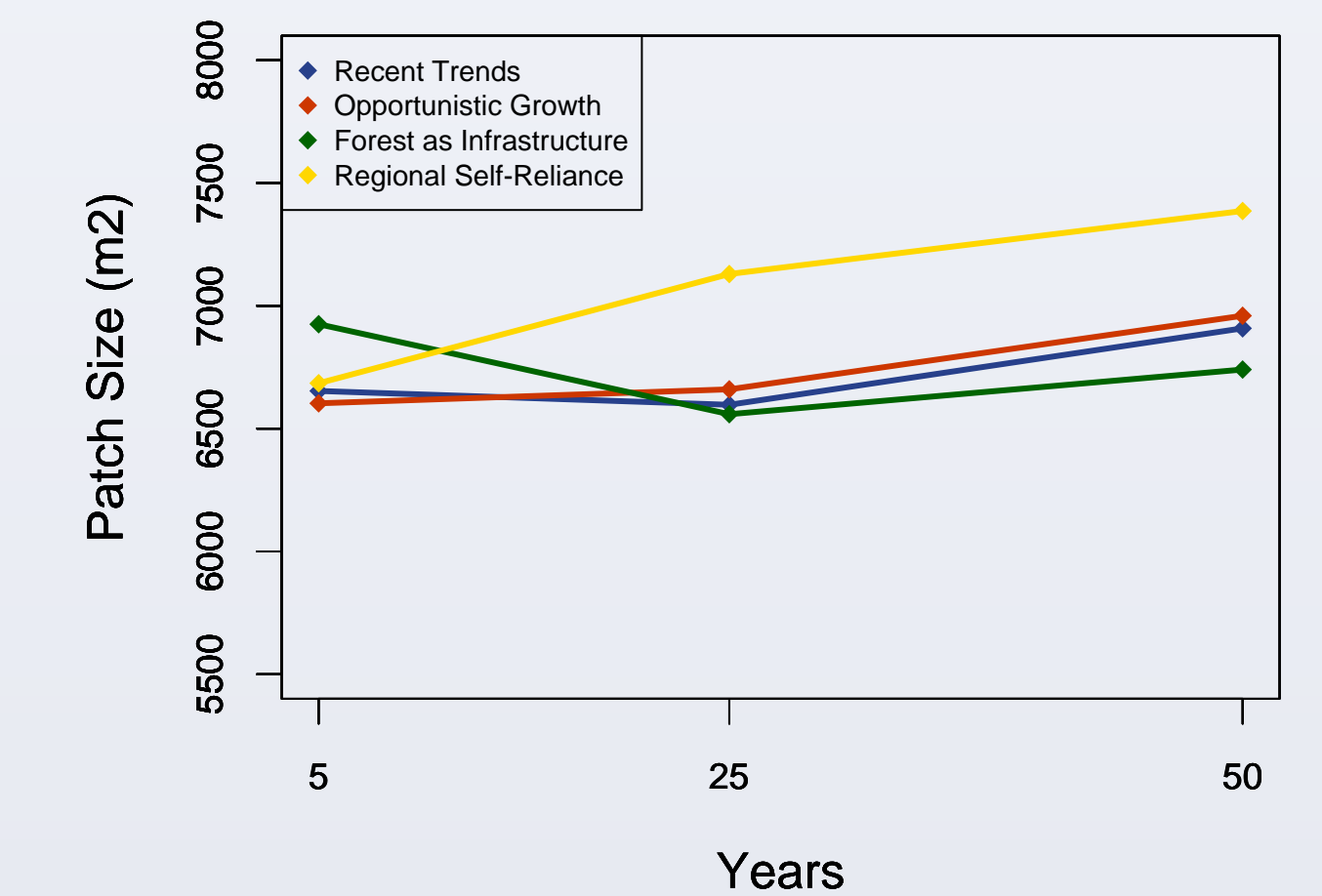
CONCLUSIONS

- Hostpot area increased in all land-use scenarios. Increases occurred for two reasons: (1) Land use concentrated services into a smaller area or (2) New services emerged in the scenario (e.g. timber, agriculture)
- Hotspot distribution across a landscape can be influenced by conflicting land-uses and a number of complex interactions between land use and heterogeneous landscape that affect density and patch formation.
- This multi-service, multi-scenario assessment can inform policymakers regarding the potential consequences of land-use and assist them in identifying priority conservation zones.

REFERENCES

Blumstein, M., Thompson, J. R. (2015). Land-use impacts on the quantity and configuration of ecosystem service provisioning in Massachusetts, USA. *Journal of Applied Ecology*.

Thompson, J., Fallon-Lambert, K., Foster, D., Blumstein, M., Broadbent, E., Almeyda-Zambrano, A. (2014). Changes to the Land: Four Scenarios for the Future of the Massachusetts Landscape. Harvard Forest, Harvard University.

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