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Land Tender: A collaborative, cloud-based decision support platform for forest management and wildfire risk mitigation in the Anthropocene

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We need forests

>1.6 billion

people worldwide rely directly on forests for their livelihoods

70%

of accessible water on Earth originates from forests

80%

of terrestrial biodiversity is in forests

>30%

of human CO_2 emissions are sequestered by forests

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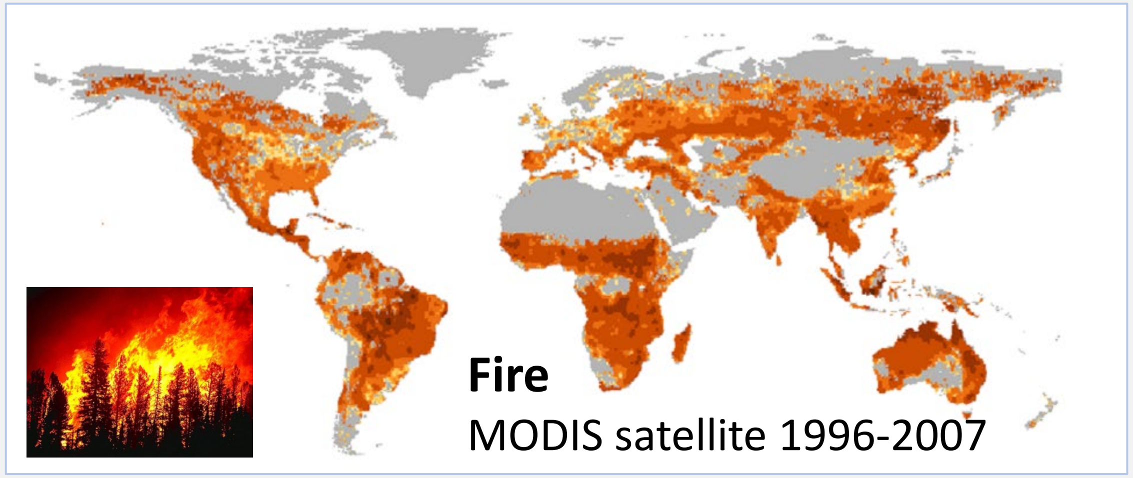
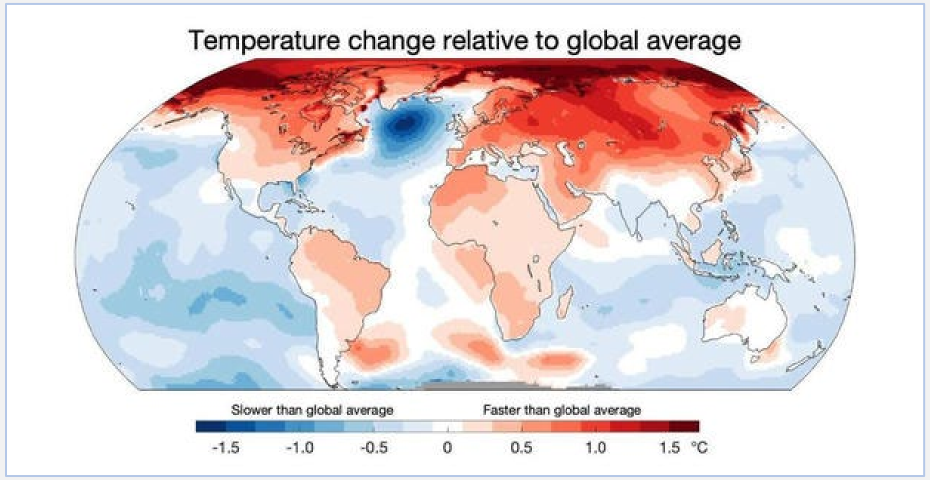
The world's forests are experiencing rapidly increasing scales and velocities of degradation

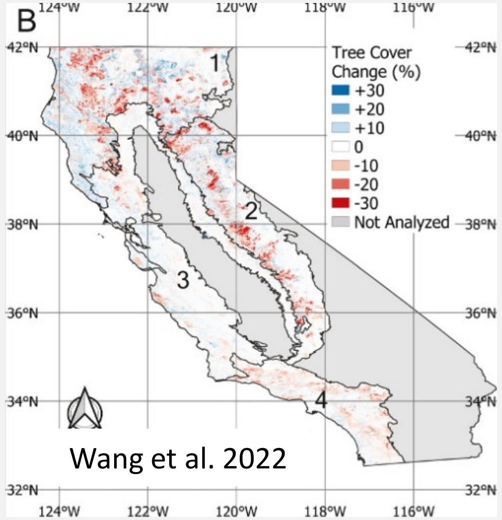


Fire
MODIS satellite 1996-2007



Climate warming
NCAR 2021

Forest loss: California
1985-2021



Wang et al. 2022

Pests and disease
Sierra Nevada
2012-2016

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Current trends in US wildfires

Estimated insured loss, 10 most destructive wildfires in US history (until 2022)

Rank	Date	Name, Location	Structures destroyed	Deaths	Insured loss ($ millions)	2022 dollars ($ millions)
1	Nov. 8-25, 2018	Camp Fire, CA	18800	85	10000	11836
2	Oct. 8-20, 2017	Tubbs Fire	5640	22	8700	10522
3	Nov. 8-12, 2018	Woolsey Fire, CA	1600	3	4200	4971
4	Oct. 20-21, 1991	Oakland Hills Fire, CA	3290	25	1700	3691
5	Oct. 8-20, 2017	Atlas Fire, CA	780	6	3000	3628
6	Sep. 27-Oct. 19, 2020	Glass Fire, CA	1520	0	2900	3381
7	Aug. 16-Sep. 22, 2020	CZU Lightning Complex, CA	1490	1	2430	2865
8	Dec. 4-Jan. 12, 2017	Thomas Fire, CA	1070	21*	2250	2723
9	Dec. 30-31, 2021	Marshall Fire, CO	1084	2	2500	2675
10	Aug. 17-Oct. 2, 2020	LNU Lightning Complex, CA	1491	6	2250	2579

CalFire: calfire-website/our-impact/fire-statistics/featured-items/top20_destruction.pdf; Insurance Information Institute: https://www.iii.org/fact-statistic/facts-statistics-wildfires

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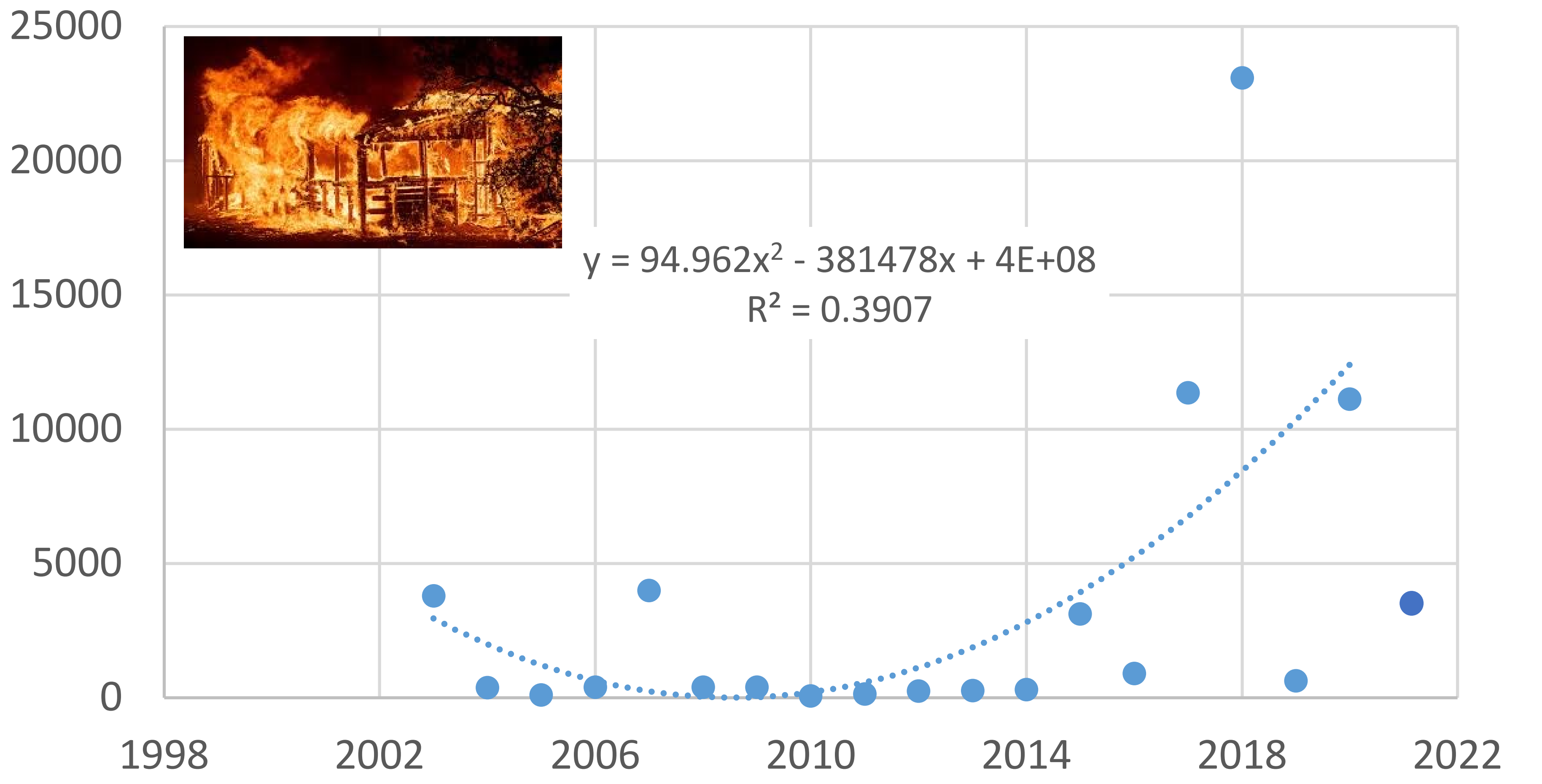
California: Structures destroyed by wildfires 2003-2021



Safford et al. 2022

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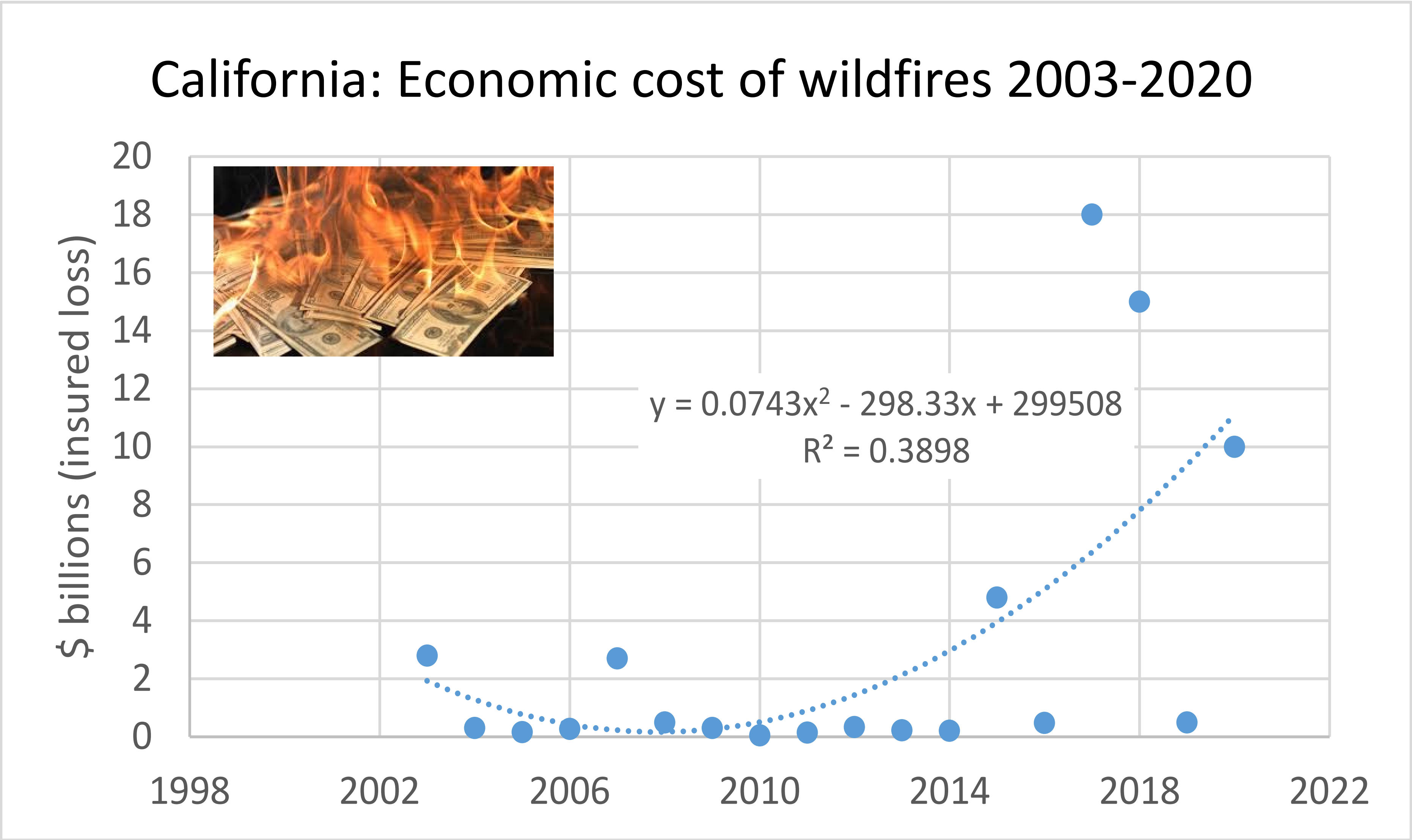
Only insured losses!



Safford et al. 2022

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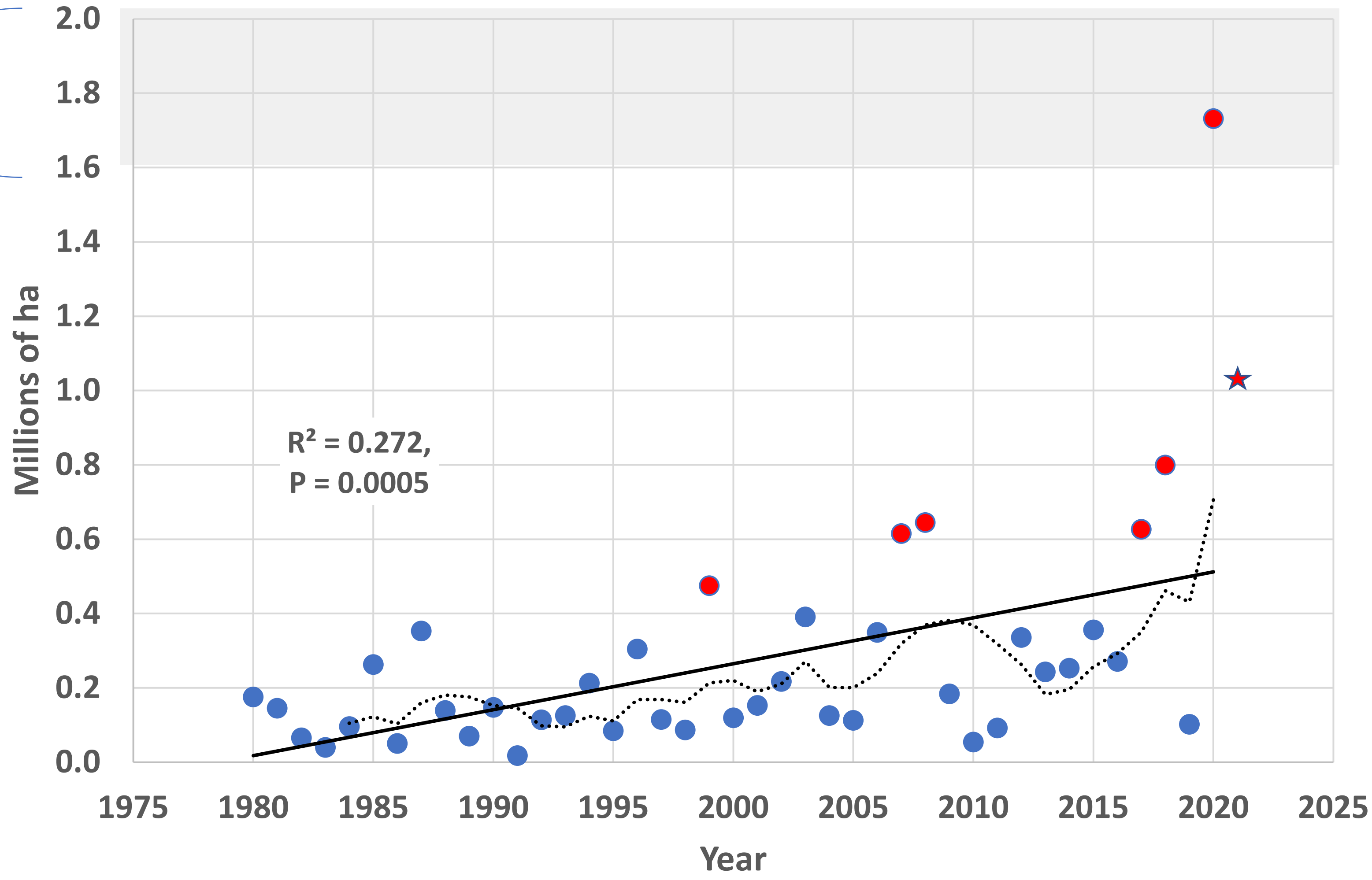
Area burned in California Wildfires 1980-2021

Probable range of burning in CA pre-1850*



*Stephens et al. 2007 *For Ecol Mgt*

Safford et al. 2022

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There are many barriers to avoiding or repairing forest degradation

- Funding/investment
- Diminishing economic and social connectivity to forest
- Institutional and workforce capacities
- Jurisdictional differences
- Varying stakeholder viewpoints and interests
- Changing conditions
- Inefficient/insufficient science-management interaction
- Lack of management and investment prioritization frameworks

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Forest sustainability is becoming a wicked problem

A wicked problem is a problem that is difficult to solve because

- Knowledge is incomplete or contradictory
- There are many people and opinions involved
- Conditions and requirements are changing
- There is a large economic burden
- There is much interconnection between this problem and other problems

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The complexity of the forest sustainability wicked problem is a major challenge to rapid and concerted management response

Complex, multijurisdictional management problems on large landscapes require collaborative planning

Collaborative planning is typically difficult, slow, and expensive

How do we:

- Efficiently incorporate stakeholder input and provide effective interfaces for client engagement?
- Generate relevant data and analytical outputs that managers and stakeholders can understand and manipulate?
- Cogently prioritize investments and link them to management actions and economic and ecosystem service outputs on the ground?
- Do this all at a minimum of difficulty, time, and cost?

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Land Tender is a cloud-based, visual scenario building and decision support tool for complex, collaborative planning efforts

Learn more

Intro video to Land Tender: 2.5 minutes

https://www.vibrantplanet.net/landtender

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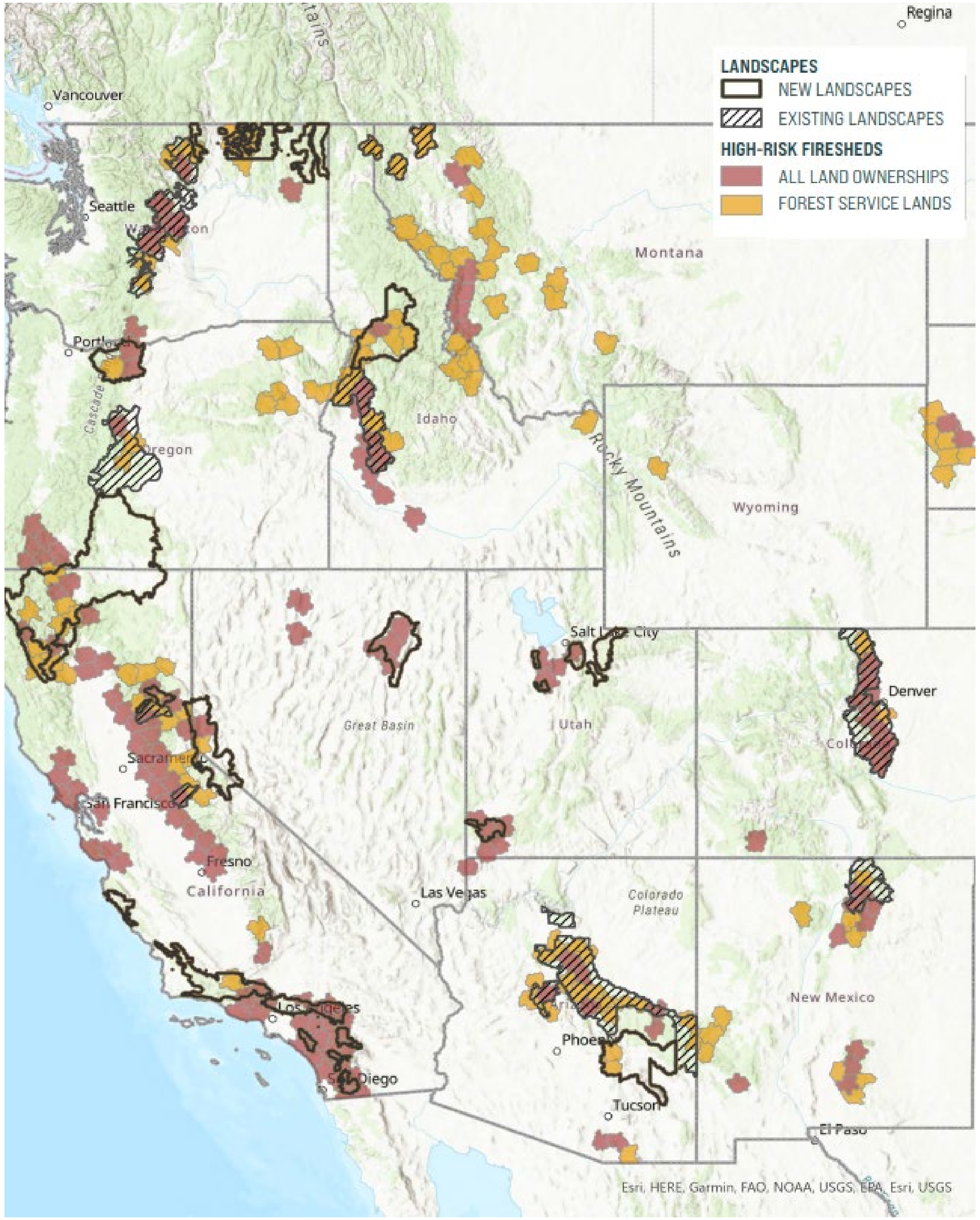
US Forest Service Wildfire Crisis Strategy Landscapes

- $3.2 billion from BIL and IRA
- Based on modeled wildfire risk to human communities and assets
- Land Tender chosen as preferred planning tool for 6 landscapes (one already completed)



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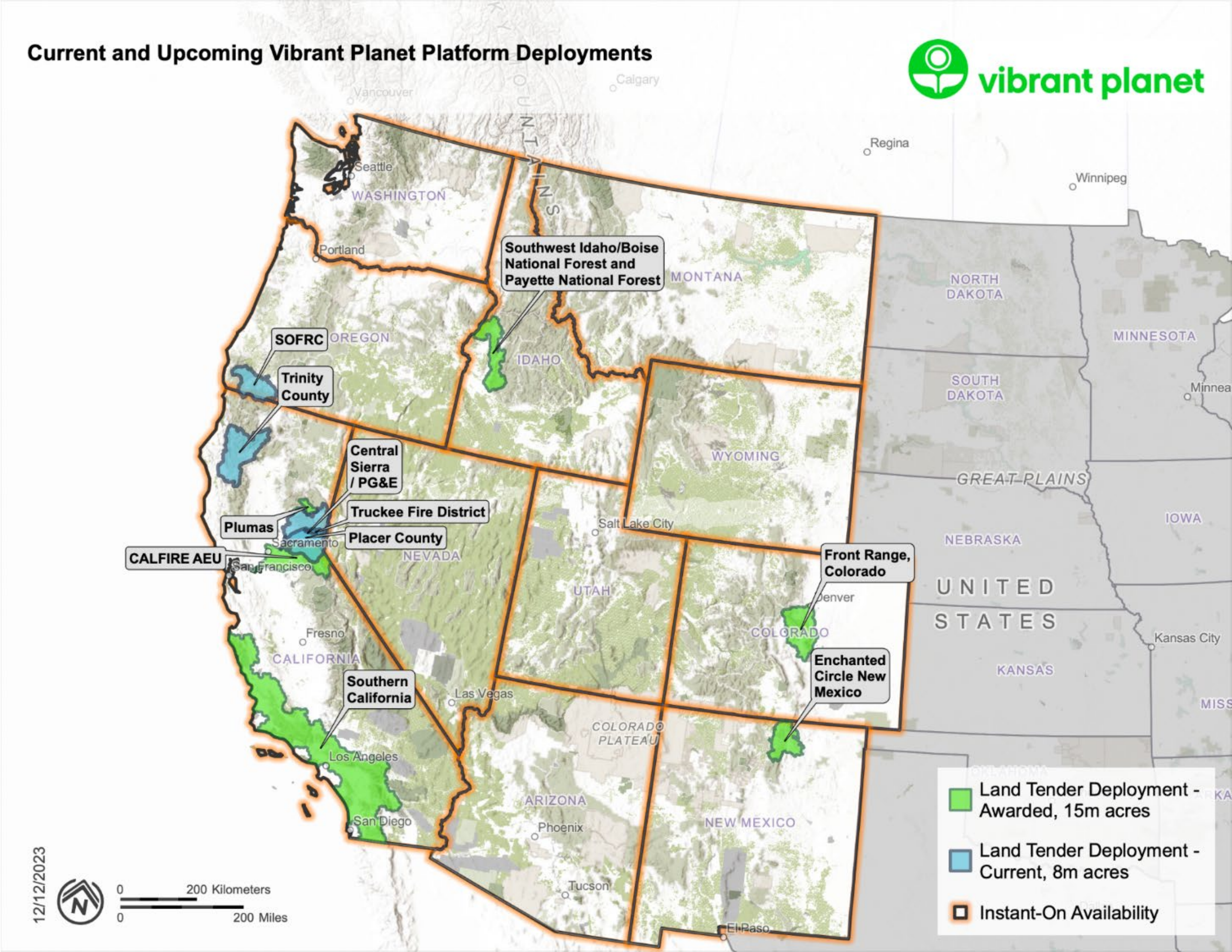
Current and upcoming Land Tender deployments



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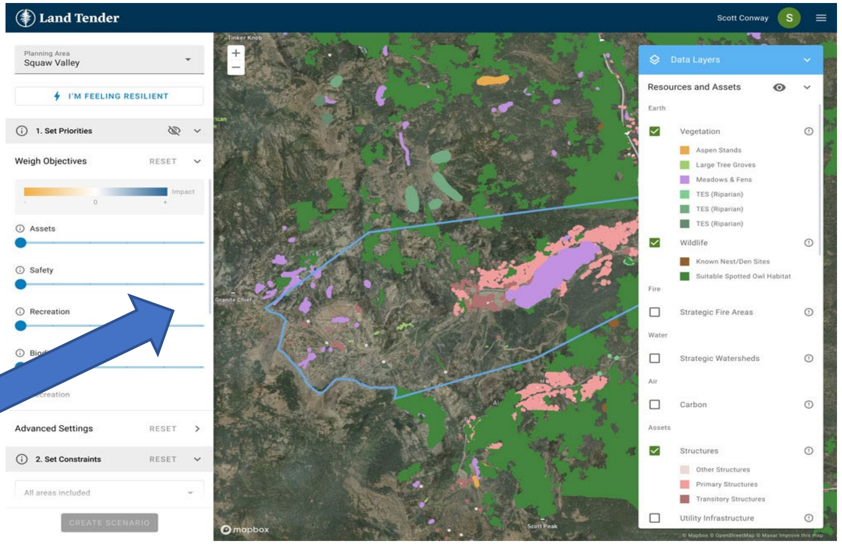
Land Tender workflow summary

Data layers input and normalized

- Vegetation types
- Vegetation structure and fuels
- Soils and hydrology
- Biodiversity data
- Infrastructure…



ID of strategic areas, resources, and assets (SARAs)

- Mix of a priori/top-down ID and stakeholder input

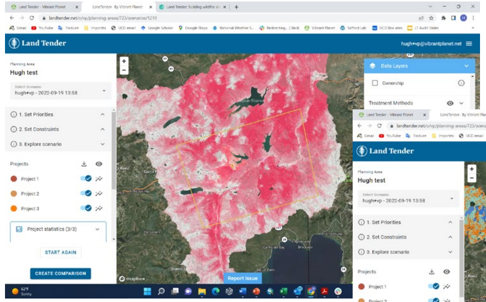
Build SARA response functions = vulnerability

- How do the key risk factors affect SARA status?
- Ranked or continuous responses, based on disturb. levels

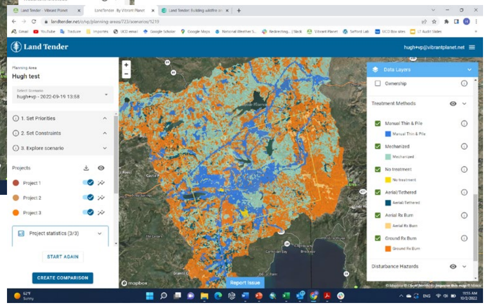
Risk assessment and development of steward-ship atlas (“STELA”)

- Risk = (Hazard Prob * Intensity)*(Exposure*Vulnerability)
- Summarizes recommended mgt actions to reduce risk

Wildfire hazard (from Pyrologix)



STELA



Land Tender workflow 2

Restorative return on investment (RROI)

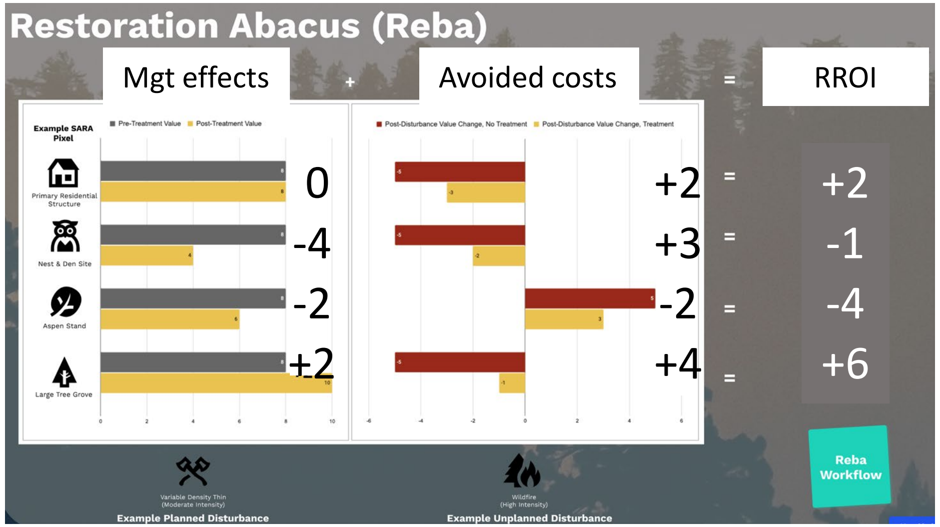
- Sum of the quantified ecosystem effects of mgt actions and the STELA treatment-driven avoided costs

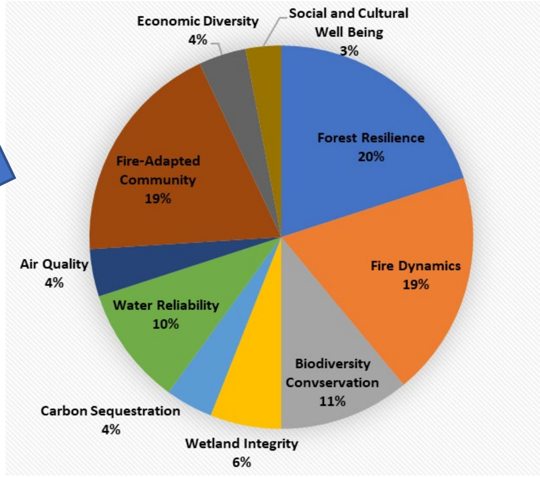
Prioritization of mgt actions from optimization model

- FORSYS (Ager 2013, 2019): Sequences actions based on (R)ROI & user-weightings of "Priority Categories" of SARAs
- Priority Categories include: watershed values, biodiversity conservation, carbon sequestration, economic outputs, human safety and asset protection…

Land Tender outputs include

- Spatial and tabular comparison of mgt alternatives
- Projected costs and relative benefits of alternatives across SARA resilience categories
- Economic outputs and ecosystem service impacts and benefits





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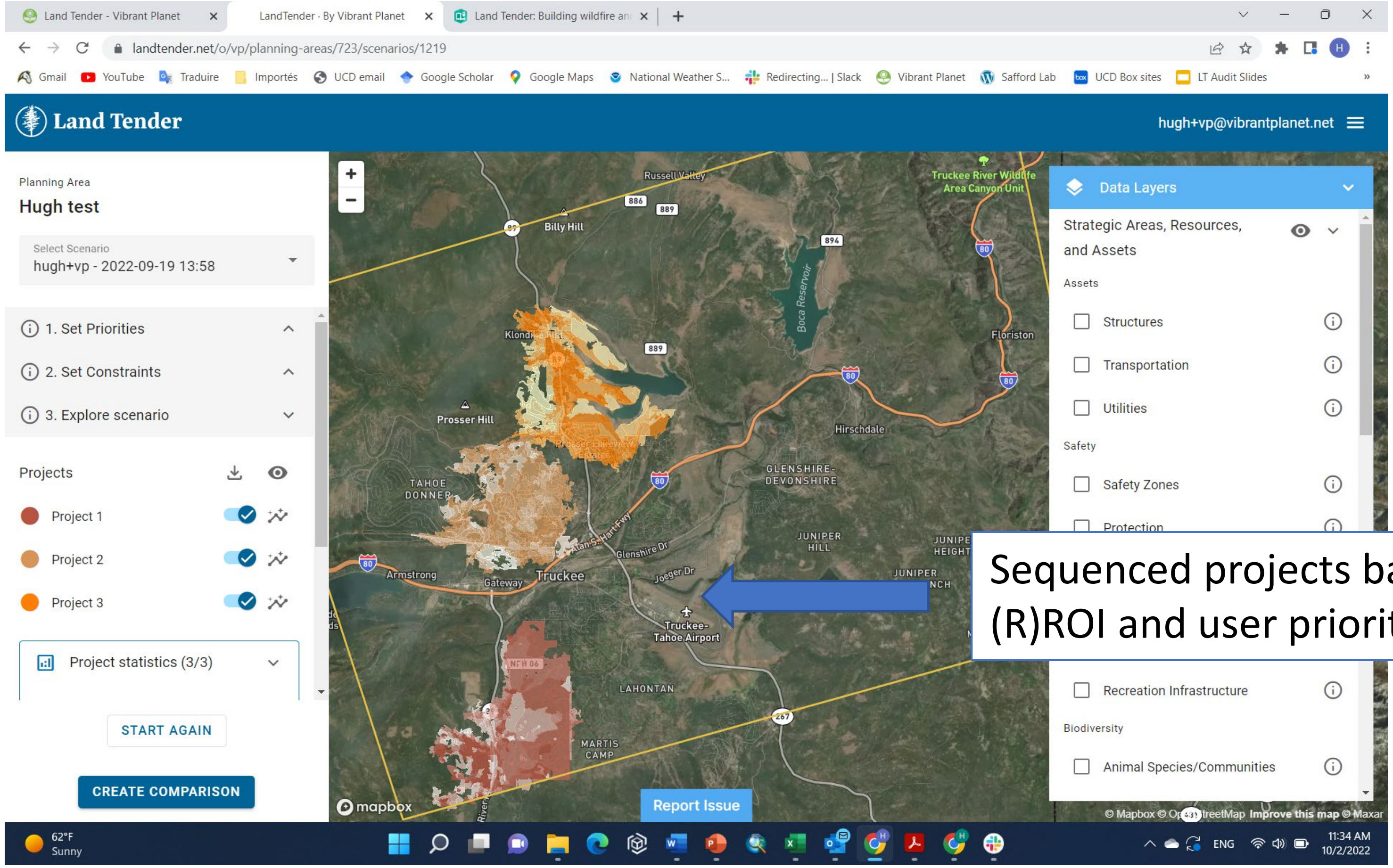
Output examples



Sequenced projects based on (R)ROI and user priorities

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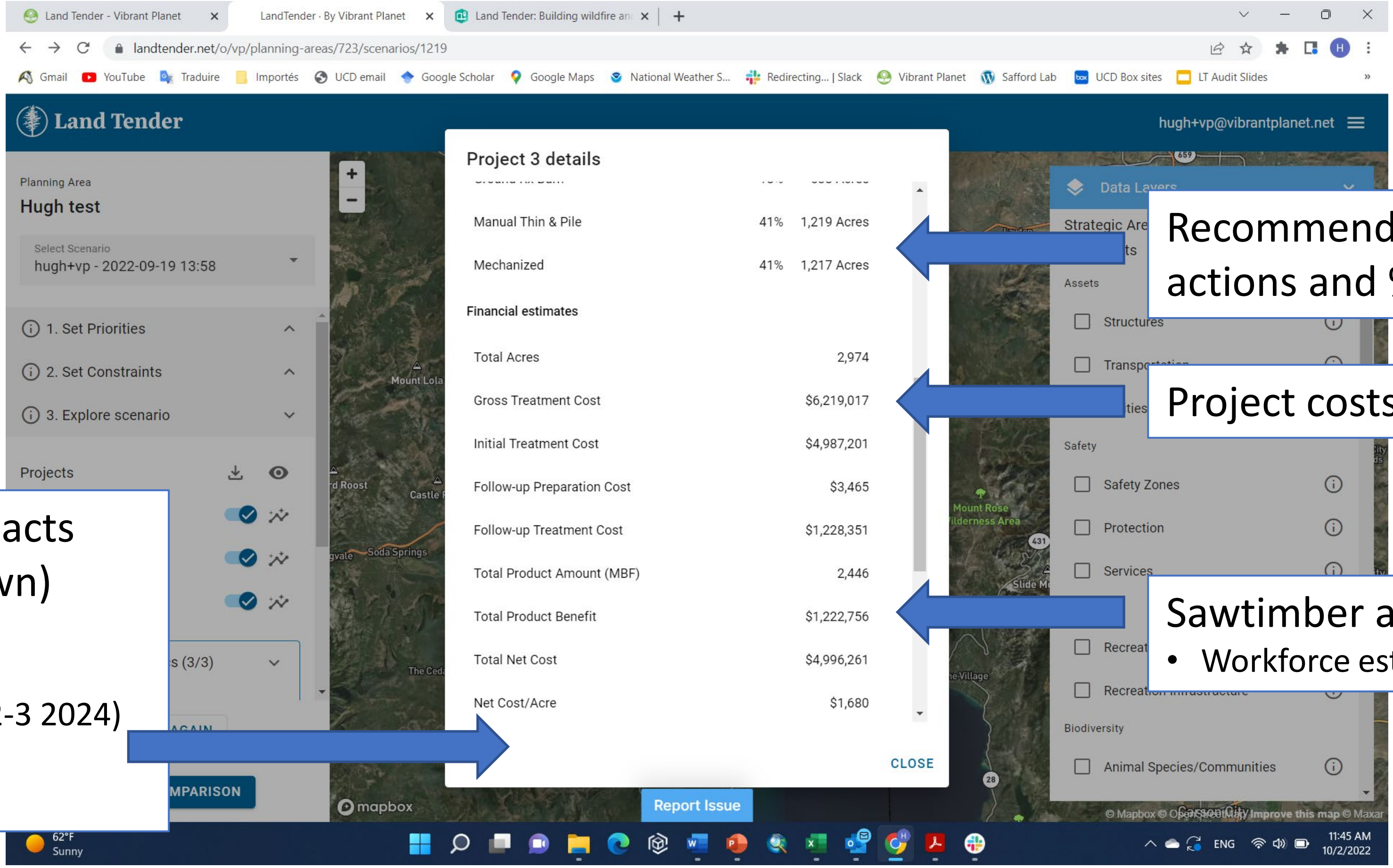
Output examples



Recommended risk reduction actions and % of project area

Project costs

Sawtimber and biomass outputs ($)
- Workforce estimates (Q1 2024)

Ecosystem service impacts and benefits (not shown)
- Aboveground tree carbon
- ET, surface water runoff & groundwater recharge (Q2-3 2024)
- Biodiversity (Q2 2024?)

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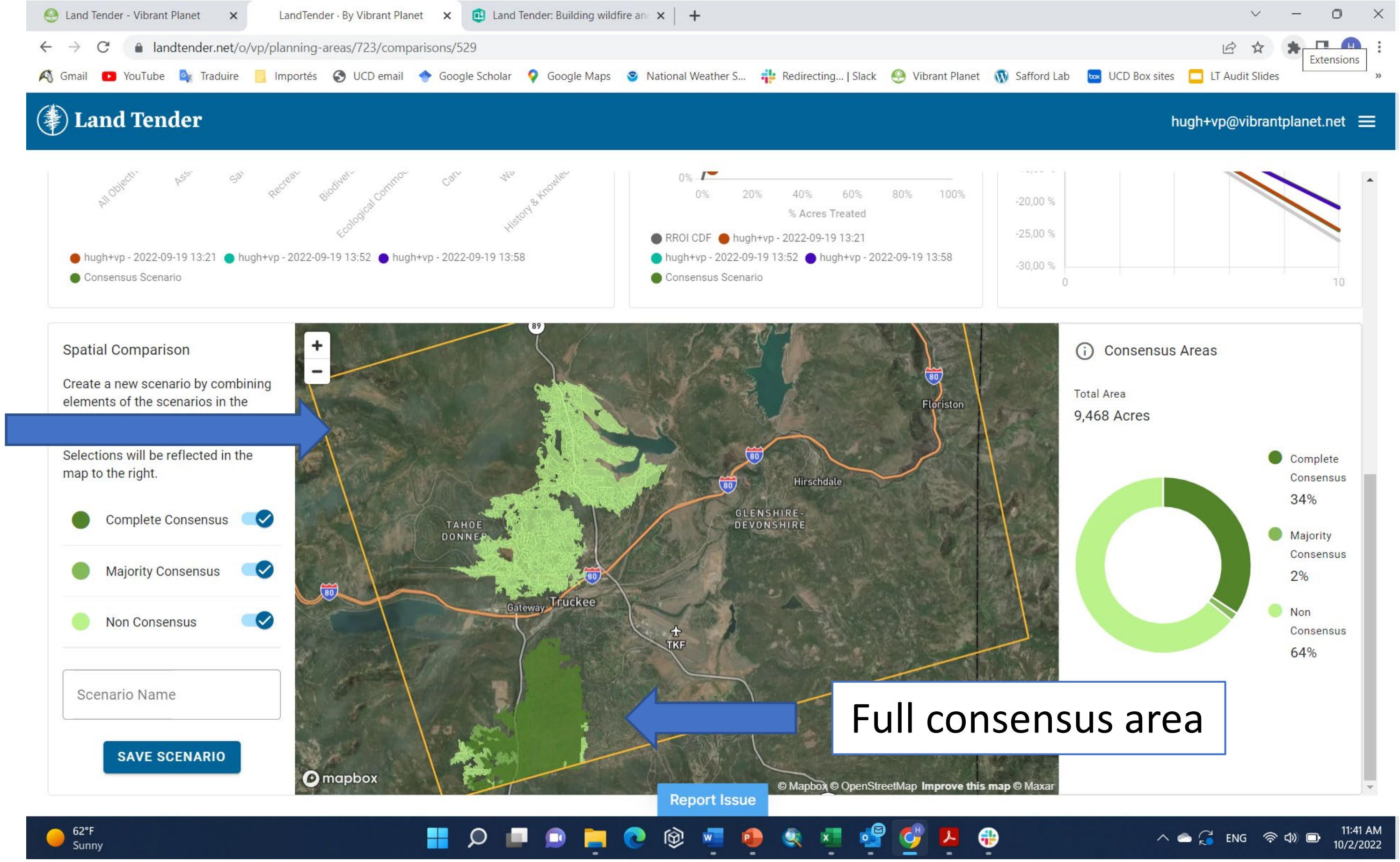
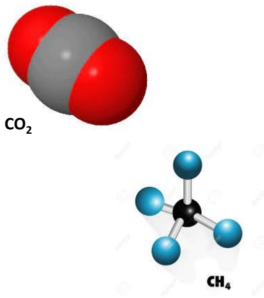
Output examples

Spatial comparison of project scenarios developed by
- "Environmentalist"
- "City council member"
- "Agency manager"



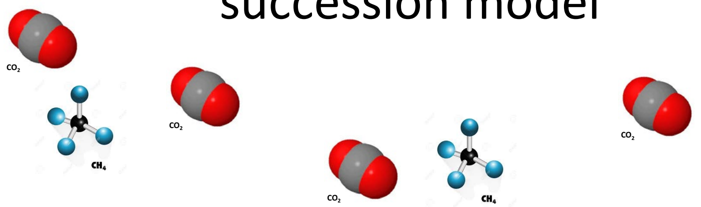
Full consensus area

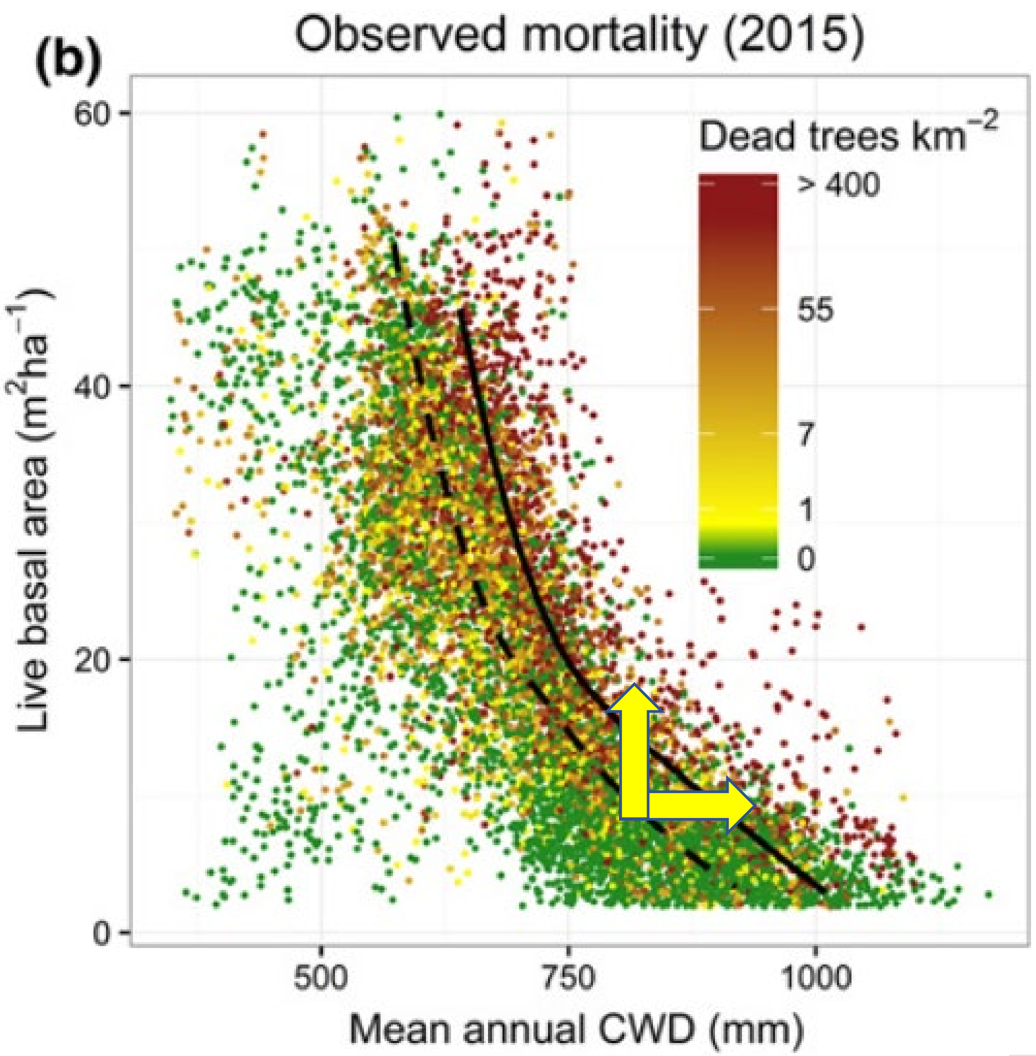
Climate change



Climate change effects can be included by, e.g.:

- Climate scenario-driven modifications to risk factor occurrence and intensity
- Feeding climate change scenarios (RCP 4.5 and 8.5) into an underlying disturbance and succession model

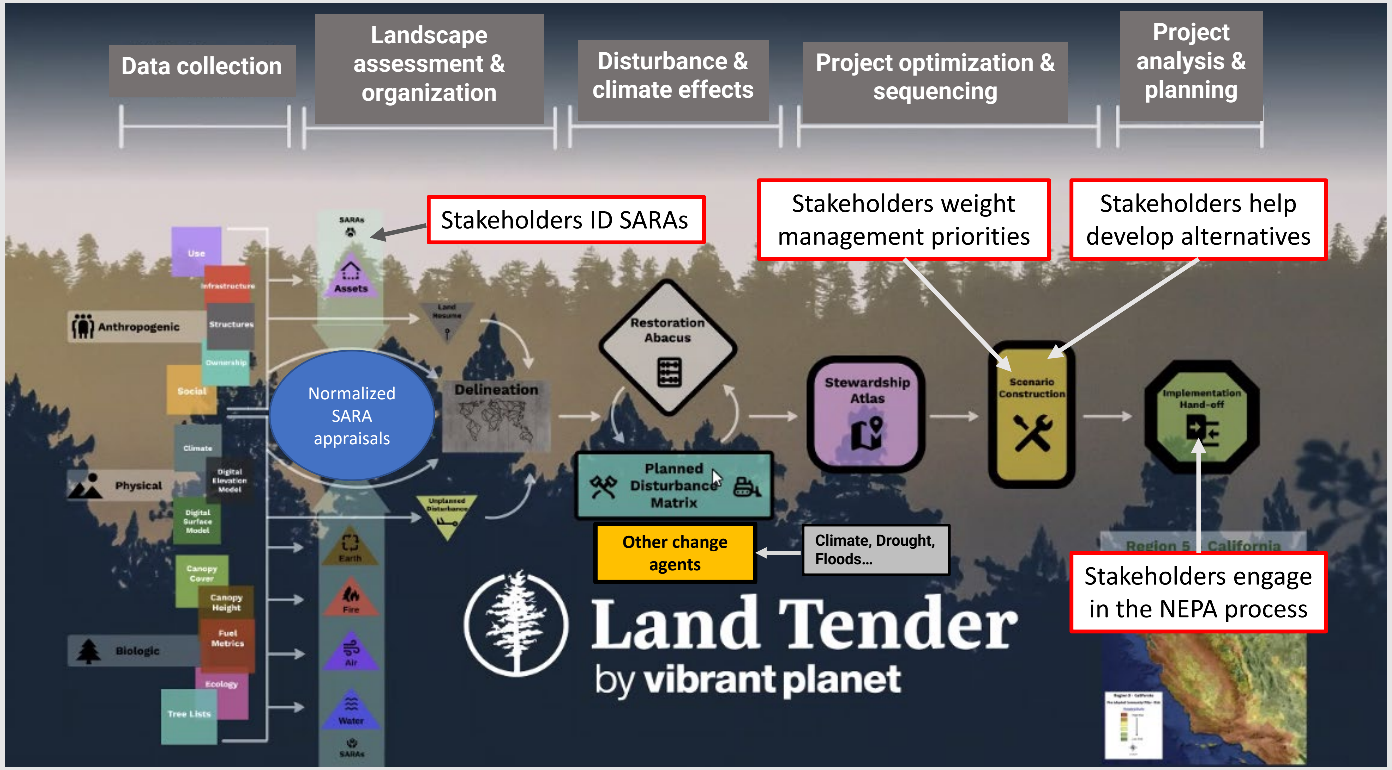




Young et al. 2017

Stakeholder participation

Stakeholders engage with LT collaboratively throughout the work-flow.



- Users visualize mgt action tradeoffs, prioritizations, and sequencing.
- Project participants share and compare their preferred scenarios and arrive at consensus or a range of mgt alternatives quickly and efficiently

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Mediterranean-type forest,
Baja California, Mexico


Boreal forest,
Åland, Finland

Land Tender highlights

- Links strategic planning with management actions
- Prioritizes and sequences mgt options, based on stakeholder values and treatment return on investment (ROI)
- Estimates costs, economic outputs, and ecosystem service outcomes
- Accessible and understandable analytics and outputs, cloud-based workflow = rapid and real time
- Stakeholders have input at multiple steps of the workflow
- Unlimited geographic scope
- Facilitates unbiased and consistent decision-making processes
- Land Tender deployment can cut months to years and many $s from typical planning processes in collaborative landscape mgt

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THANK YOU!
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Details on ForSys optimization routine

ForSys version used in Land Tender uses the “patchmax” heuristic, which uses a search approach based on Dijkstra’s algorithm (Dijkstra 1959)

Optimization approach

The optimization problem at hand is to locate a project area within the larger landscape (e.g., national forest district) and select stands for treatments to maximize the protection of PPOG from potential wildfire losses. Both the location of the project area and the treatment of individual stands can potentially contribute to the objective (PPOG). Specifically, the restoration objective value can be defined as

$$\text{Max}\sum_{j=0}^{k}\left(Z_j N_j^T + (1 - Z_j)N_j^{NT}\right)$$

where Z is a vector of binary variables indicating which of the k stands are treated (e.g., $Z_j = 1$ for treated stands and 0 for untreated stands), N_j^T is the post-wildfire number of PPOG in stand j if treated, and N_j^{NT} is the post-wildfire number of PPOG in stand j if not treated. The solution has a spatial constraint because the collection of both treated and untreated stands in the project area needs to create a contiguous area within which the potential fire behavior is acceptable to managers for future use of landscape fire treatments (prescribed fire treatments and managed wildfire) to maintain fire-adapted conditions over time. Thus neither the treated nor untreated stands within the project can have a potential fire behavior that exceeds a management threshold, i.e., one that would prevent the liberal use of prescribed fire or trigger suppression activities during a wildfire being managed for restoration objectives. Spatial contagion of the low hazard condition creates a container within which free-burning wildfires and prescribed fires can be managed with a lower risk to managers, resulting in reduced suppression efforts over time, and increases in the use of fire to manage fuels. This constraint is important since risk from both prescribed and managed fires poses ongoing challenges to the expanded use of fire in restoration (Graham et al. 2012).

Ager, et al. 2013. Ecosphere 4(2):29

Further ForSys details

Heuristic, spatial model

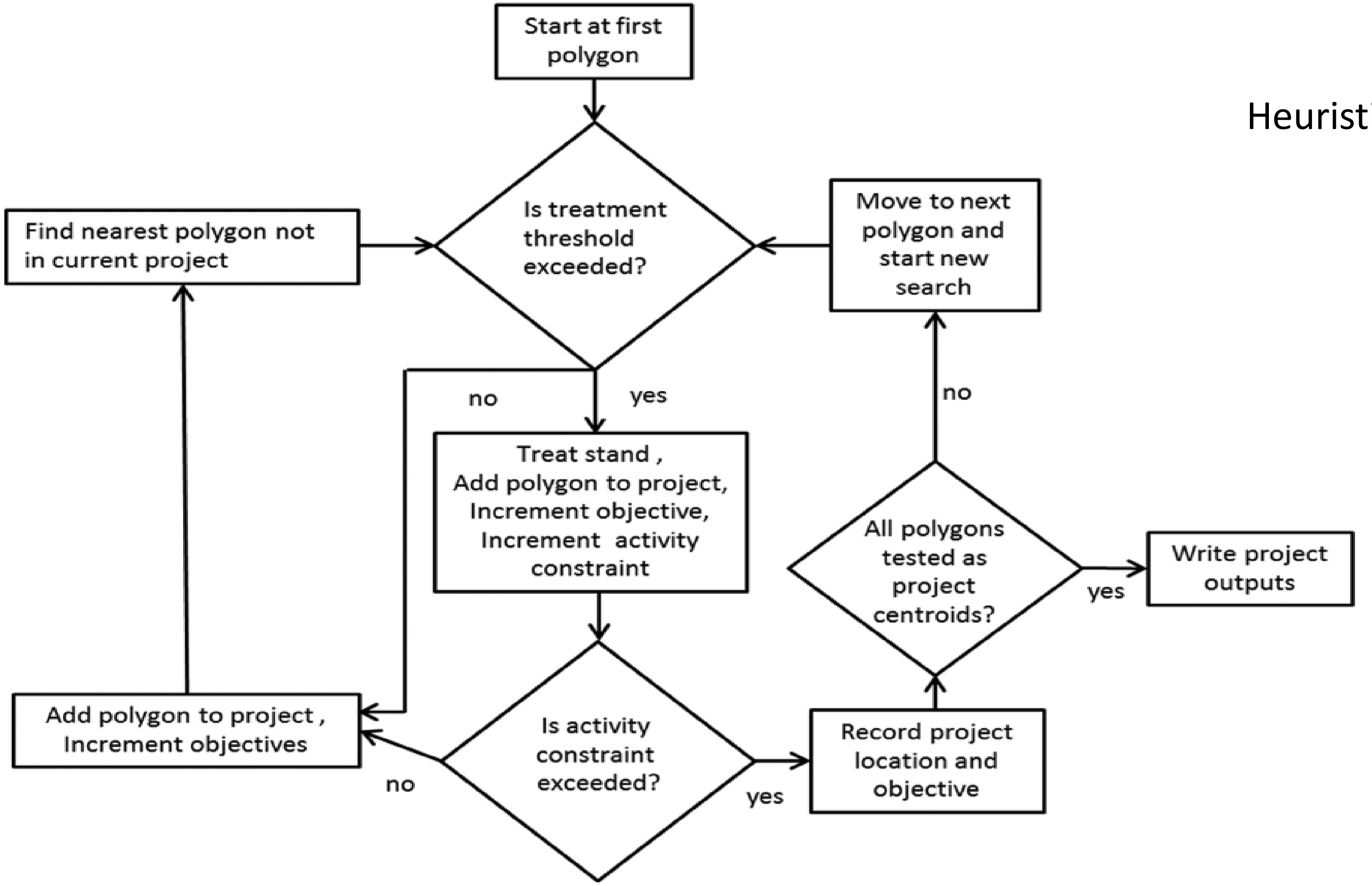

Fig. 3. Decision logic for the optimization model used to locate project areas. The algorithm tests each stand as the seed location for a project, and absorbs adjacent stands until a total area treated constraint is met. Stands that exceed a predetermined fire behavior threshold require treatment. The model identifies the aggregate of polygons that maximize the restoration objective and the polygons that require treatment. In the current study, polygons were defined as stands, treatment thresholds were measured by potential flame length, activity constraint was the total treatment allowance, and restoration objective was the total predicted post-wildfire, old growth ponderosa pine in the project area.

Ager et al. 2013 Ecosphere