

Wildfire Risk and Urban Expansion in South Kohala and North Kona, Hawai‘i

Assessing new and existing areas of wildfire risk in relation to Hawai‘i’s fire history, land cover, and tree canopy, through the lens of urban expansion

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Executive summary

Hawai‘i Island has urban expansion plans that conflict with the land’s spatial characteristics and induce nearby communities’ wildfire risk. This report uses the new Tree Canopy Viewer (TCV) dataset to geospatially analyze projected urban expansion wildfire risk coupled with an evaluation of current strategic documents to inform opportunities to mitigate wildfire risk for Hawai‘i Island.

Background

Cities are looking to tree canopies as the solution to address environmental and socio-economic problems exacerbated by climate change. Trees are an important tool in city land management and climate action plans for achieving stormwater reduction, carbon sequestration, and decreased energy consumption goals (Turner-Skoff & Cavender, 2019; Vailshery et al., 2013). In Hawai‘i, urban and peri-urban trees also have potential to mitigate increased wildfire risk associated with urbanization.

Hawai‘i Tree Canopy Viewer

The TCV is a 1-meter resolution LiDAR and MAXAR Vivid imagery raster layer that displays state-wide tree canopy and supplementary sociodemographic, economic, health, and environmental data layers (*HI Division of Forestry and Wildfire*, 2023). This tool, developed by the Hawai‘i Division of Forestry and Wildlife and the USDA Forest Service, reveals relationships between tree canopies and communities disproportionately affected by socioeconomic and environmental risks. This report uses the TCV in geospatial analysis to explore the relationship between tree canopy, urban expansion, and wildfire and opportune areas to mitigate wildfire risk.

Benefits of urban trees in Hawai‘i

Hawai‘i tree canopies reduce the urban heat island effect (Shahidan et al., 2012) and have cascading effects on ecosystem function, reducing fire fuel loads, and facilitating tree seedling establishment in grassland ecosystems (Keller et al., 2012). Endemic trees also possess traditional values in their use for canoes, thatch, medicines, current day furniture, and woodcraft (Daehler et al., 1999). Wildfire decreases tree canopy benefits and increases community wildfire risk.

Threats to Hawai‘i Island’s tree canopy- land cover change and fire

Fire exacerbated by projected drought and land cover change threaten Hawai‘i’s tree canopy (Kellner et al., 2012; Longman et al., 2023). Fire was a controlled disturbance for agricultural purposes used by early Polynesian settlers in Hawai‘i. Fire promoted pia (*Tacca leontopetaloides*) and ‘ama‘u (*Sadleria cyatheoides*) for food (Kirch, 1982) and pili grass (*Heteropogon contortus*) for thatch (Daehler and Goergen, 2005). European land colonization and the abolishment of ahupua‘a in the early 1800s, traditional land tenure systems (Gonschor & Beamer, 2014; Easter et al., 1991), converted this productive native dry forest landscape to pastureland (Trauernicht et al., 2015). This change in land management introduced nonnative grasses such as kikuyu grass (*Cenchrus clandestinus*), fountain grass (*Cenchrus setaceus*), molasses grass (*Melinis minutiflora*), and Guinea grass (*Megathyrsus maximus*) and nonnative ungulate grazing that decreased tree canopies and encouraged nonnative grass cover (Zhu et al., 2021; Hawbaker et al., 2017).

Nonnative grass species fuel wildfires in dry forest ecosystems on the leeward side of Hawai‘i Island near urban development (Kellner et al., 2012; Aplet et al., 1998; Hughes et al., 1991). These fire adapted grass species quickly regenerate after fire and anthropogenic behaviors perpetuate this fire behavior cycle (Trauernicht et al., 2015). Land cover change coupled with a projected increase in droughts, increases landscape flammability (Bremer et al., 2018) and wildfire occurrence and risk (Frazier et al., 2022; Trauernicht, 2019).

Projected urban expansion on Hawai‘i Island

Humans are the primary wildfire ignition source in Hawai‘i with ignitions most prevalent in developed landscapes (Trauernicht et al, 2015) where wildfires become uncontrollable and place people, values and native ecosystems and forested watersheds at risk. Therefore, communities in the wildland urban interface (WUI), the area where anthropogenic development infringes on the natural environment (Hawai‘i Emergency Management Agency, 2018; Kaval et al., 2006) bear greater fire risk.

Hawai‘i Island has plans for urban expansion, native species restoration, increasing tree canopy, and wildfire risk mitigation in the WUI. However, district, county, and state plans often do not align in their goals or approach (Beverly et al., 2010) creating challenges between management values. Some plans explicitly address gaps in land cover change impacts on wildfire risk and identify wildfire in the WUI as a priority area of concern for natural resource managers (DLNR Division of Forestry and Wildlife, 2016). Therefore, there is a need to understand the implications of urban expansion on wildfire risk (Lampin-Maillet et al., 2011) and various land management goals’ support for wildfire mitigation and adaptation in the WUI (Depietri & Orenstein, 2020).

Integrating land cover change into wildfire risk assessment using the TCV

Past, present, and future anthropogenic factors decrease Hawai‘i’s tree canopy and promote nonnative grass species, increasing wildfire risk. The TCV contains data to assess the wildfire risk of projected urban expansion in relation to current land cover. This report aims to analyze:

1. Land cover impacts on wildfire behavior reflected in state, county, and district plans
2. The geospatial relationship between tree canopy, urban expansion and fire risk
3. Projected urban expansion impacts on wildfire risk

Methods

Study area

South Kohala and North Kona are districts in the County of Hawai‘i with respective populations of 19, 310 and 43, 313 (United States Census Bureau, 2020). These districts are on the leeward side of Hawai‘i Island characterized by a tropical dry, warm, and windy climate (Bremer et al., 2018) with annual rainfall between 204-750 mm (Giambelluca et al., 2013) and 751-1350mm and average temperatures ranging between 61-70 °F (Longman et al., 2023 & 2021). This landscape hosts native flora such as wiliwili trees (*Erythrina sandwicensis*) and endangered uhiuhi trees (*Mezoneuron kavaiense*) (The County of Hawai‘i Planning Department and Townscape, INC., 2008), and fauna such as palila (*Loxioides bailleui*), ae‘o (*Himantopus mexicanus*) and Hawai‘i ‘elepaio (*Chasiempis sandwichensis*) (Department of Land and Natural Resources, 2023; Frazier et al., 2022). Current land uses include conservation, agriculture, rural and urban, with a history of dry forest land cover conversion to nonnative grass dominated pastureland (Trauernicht et al., 2015). Average rainfall for this site has steadily decreased and is projected to continue as average temperatures rise by the end of the 21st century (Timm et al., 2015; Longman et al., 2023) increasing drought events.

Analyzing state, county, and district plans for discrepancies between wildfire risk mitigation and land cover goals

Publicly available plans were identified for analysis from county websites (Table B1) using search words such as “climate change goals” and “land development plan” to understand how the county considers wildfire risk and mitigation strategies in land management plans. I performed a comprehensive review of selected plans and identified management themes of “urban expansion,” “wildfire risk,” “land cover change,” “climate change,” “wildfire adaptation and mitigation”. Excerpts that acknowledged these themes were extracted to a Microsoft Excel spreadsheet that was simplified to a summary graphic to represent the presence of identified themes.

How do state, county, and district environmental plans support wildfire risk mitigation?

Publicly available plans were selected from state and county websites (Table B2) using search words such as “climate action”, “sustainability”, and “environmental goals” to examine support for wildfire mitigation and adaptation goals. Excerpts that included “tree canopy”, “invasive or nonnative species removal”, “native species reforestation”, and “fire risk reduction” goals were extracted to a Microsoft Excel spreadsheet and classified on whether they exist independently, as a means of wildfire mitigation and adaptation, or were excluded from the plan. Searches were expanded to phrases inclusive of selected goals when verbatim searches produced minimal responses. For example, the County of Hawai‘i General Plan (2005) does not include the term “tree canopy,” but mentions a goal to “[...] retain and re-establish forest cover in upland watershed areas with emphasis on native forest species” therefor, this plan was classified as one with a standalone goal.

Where is projected urban expansion in relation to existing communities at risk from wildfire?

A new project file created on ArcGIS Pro 3.1.1 software included feature layers “Fire Risk Areas”/Communities at Risk from Wildfire and respective risk ratings, and “Hawai‘i County Land Use Plan Allocation Guide” (LUPAG), from the Hawai‘i Statewide GIS Program Geospatial Data Portal that were clipped to South Kohala and North Kona “Judicial District Boundaries”. I created a new feature layer that exclusively displayed “urban expansion” polygons from the LUPAG and added it to the project map. A one-mile WUI buffer was created around Communities at Risk from Wildfire as defined by the Hawai‘i Forest Action Plan (2016).

What is the land cover of projected expansion?

I downloaded the 2020 Tree Canopy Viewer raster dataset for Hawai‘i County from The Division of Forestry and Wildlife and the U.S. Forest Service website and imported it to the existing ArcGIS project. Then, I created one feature layer with Urban Expansion and Communities at Risk from Wildfire and their respective WUI boundaries. The “Carbon Assessment of Hawai‘i Land Cover Biome Unit” feature layer was downloaded from the Hawai‘i Statewide GIS Program Geospatial Data Portal and uploaded to the GIS project and clipped to the newly merged Communities at Risk from Wildfire and Urban Expansion WUI boundaries. A new feature layer was created with broad “alien” and “bare ground” land cover types as well as for “native species” general land cover.

What land cover type have fires historically burned in?

Historical fire areas between 1984 and 2019 from the Monitoring Trends in Burn Severity (MTBS) Interactive Viewer for Hawai‘i state and fire points from the National Interagency Fire Center- Wildland Fire Incident Locations from 2000- present, were extracted and clipped to South Kohala and North Kona Judicial District Boundaries. Alien, bare ground, and native land cover types were then clipped to the fire polygons to reveal land cover in the historically burned sites.

Results and Discussion

Discrepancies between plans in addressing wildfire and land cover change

Eight plans acknowledge wildfire risk presence and others misalign in wildfire risk mitigation and urban expansion goals (Table A1). The South Kohala Community Development Plan (CDP) acknowledges all management themes while the County of Hawai‘i General Plan and Kona CDP excludes high wildfire risk exacerbated by land cover change, likely due to the narrower scope of the two plans (Table A1). Furthermore, the South Kohala CDP outlines wildfire mitigation and adaptation strategies despite no county regulations in place that require residential subdivisions to participate in wildfire mitigation practices. This contrasts with the Northwest Hawai‘i Island

Community Wildfire Protection Plan (CWPP) that outlines 17 wildfire treatment recommendations for Kohala. However, these recommended practices are not supported by district or county level land management plans. Furthermore, allocated land for urban expansion in Kona exceeds land needed to accommodate population growth projections by four times (Wilson Okamoto Corporation, 2019). Ultimately, county land management plans are framed to a narrower set of perspectives and when collated with one another, land allocation does not reflect increased community wildfire risk due to land cover change.

Environmental plans support wildfire risk mitigation while others do not

Various state and county plans support one another in discrete environmental goals that serve as wildfire mitigation and adaptation strategies (Table A2). The Hawai'i Forest Action Plan (2016), County of Hawai'i General Plan (2005), and County of Hawai'i Climate Action Plan (2020) include tree planting or canopy goals that decrease fire spotting and block radiant heat (Curran et al., 2017). While not framed as wildfire risk mitigation, these goals serve that role if operationalized. Contrastingly, plans with sustainability or climate action visions (such as the County of Hawai'i General Plan, County of Hawai'i Climate Action Plan, and Hawai'i 2050 Sustainability Plan) exclude specific wildfire risk mitigation goals that would align with their scope (Table A2).

Projected urban expansion enlarges the WUI and creates new communities at wildfire risk

11,995 acres of urban expansion in North Kona occurs in existing communities at risk from wildfire (County of Hawai'i, 2005) (Table A1, Figure A1). 42% of the county's acreage allocation for urban expansion in South Kohala (12, 264 acres) demonstrates increased wildfire risk for expanding communities. Projected expansion encroaches on existing WUI boundaries and creates new communities at risk from wildfire (Figure A1). Anthropogenic fire ignitions sources are responsible for the four-fold increase in annual area burned in Hawai'i within the last century (Hawbaker et al., 2017; Trauernicht et al., 2015) and occur in developed areas (Trauernicht et al., 2018). Therefore, the projected urban expansion invites opportunities for wildfire events. Nonnative species encroachment, a drying climate, and projected urban expansion in these districts aggravate high wildfire risk (Longman et al., 2023; Hawbaker et al., 2017), placing residents, homes, businesses, and cultural values in the line of fire.

Nonnative grasses and a low tree canopy dominate urban expansion land cover

South Kohala and North Kona urban expansion protrudes into dry moisture zones with bare, alien dry forest, alien dry grassland, alien dry shrub, alien mesic forest, alien mesic grassland, alien mesic shrub, alien tree plantation, alien wet forest, alien wet grassland, or alien wet shrub general land cover; South Kohala's urban expansion also possess minimal tree canopy (Figure A2). This is the dominant land cover type of historically burned areas from wildfire in the district (Figure A3). These nonnative grass species cover 24% of the state's land area (Trauernicht et al., 2015) and are fire adapted with high fine fuel loads, ignitability, combustibility, and flame sustainability (Simpson et al., 2016). They vigorously establish in post fire environments and outcompete their native and woody counterparts, perpetuating a cycle of wildfire occurrence and spread in Hawai'i (Simpson et al., 2016; Trauernicht et al., 2015). Dry moisture zones comprised of alien/nonnative species aids fire spread and increases fire risk (Coogan et al., 2021; Trauernicht et al., 2018; Trauernicht et al., 2015; Simpson et al., 2016; Lampin-Maillet et al., 2011), vetting the projected urban expansion communities a high wildfire risk rating. Furthermore, wildfire events that decrease tree canopy and forest cover connectivity increase native species fragmentation (Balzotti et al., 2020).

This spatial analysis suggests projected urban expansion communities in South Kohala would benefit from increasing tree canopy, decreasing nonnative species coverage, and native species restoration to mitigate wildfire risk. Green firebreaks are a wildfire mitigation strategy comprised of

tree and understory species with low flammability that reduce or slow fire spread, decrease fire spotting, block radiant heat (Curran et al., 2017) and shade out fire-adapted nonnative grass species (Bremer et al., 2018; Friday et al., 2015; Trauernicht et al., 2015). Native tree and shrub species such as Koa (*Acacia koa*), ‘ōhi‘a lehua (*Metrosideros polymorpha*), and naio (*Myoporum sandwicense*) perform this role with drought hardiness and high fine fuel moisture traits (Trauernicht et al., 2018; Ellsworth et al., 2015; Smith & Tunison, 1992). Native shrubs such as ‘ilima (*Sida fallax*), ‘a‘ali‘i (*Dodonaea viscosa*), ‘uhaloa (*Waltheria indica*), and ‘ulei (*Osteomeles anthyllidifolia*) resprout in postfire conditions and should be planted in burn areas to reclaim native species presence, productivity, and expansion (Loh et al., 2009; Daehler & Goergen, 2005) in addition to pili grass (*Heteropogon contortus*) which contains a lower biomass, reducing landscape fire risk and intensity (Daehler & Goergen, 2005). The fire-adapted nonnative grass species that dominate the WUI (Figure A2) limits nonnative species’ potential to break up fuel continuity and slow fire spread (Friday et al., 2015). Therefore, green firebreaks should be used in tandem with nonnative ungulate removal, fuel thinning, and invasive species removal to reduce wildfire risk (Curran et al., 2017). These various forms of wildfire mitigation are cost-effective, successful over large spatial and temporal scales, and disrupt the positive feedback between nonnative plants and wildfire (Zhu et al., 2021; Powell et al., 2017).

Green firebreaks in the WUI can reduce wildfire spread into existing and projected communities at risk from wildfire (Bowman et al., 2018; D’Antonio et al., 2008) and promote native species restoration and tree canopy goals (Table A2). However, the 2018-2019 Vegetation Management Rapid Mapping Assessment and Collaborative Action Planning Report lacks current or proposed fuels conversion in Waimea and Puako or fuels reduction for Puako where nonnative coverage is high (Figure A2). Furthermore, a tree planting or canopy goal in the Northwest Hawai‘i Island CWPP would create opportunities for land management planning to support outlined wildfire risk mitigation strategies (Table A2). Increased synergies between state, county, and district plans and direct land management actions would aid in wildfire risk reduction.

North Kona has a greater presence and distribution of tree canopy and native species than South Kohala (Figure A3). Native species land cover that includes ‘ōhi‘a lehua, koa, and native shrubs are observed in communities at risk from wildfire and urban expansion WUI boundaries that encroach into existing tree canopy (Figure A2). The Hawai‘i Wildfire Management Organization Wildfire webapp and Pacific Fire Exchange Wildfire Area Burn Maps (Pacific Fire Exchange, 2022; (Hawai‘i Wildfire Management Organization, n.d.) also reveal fewer fire points and fewer total acres burned in North Kona than South Kohala (Figure A3). However, tree canopy is lacking in urban expansion boundaries and consists of bare or alien land cover types. This is an opportune landscape to prioritize increasing tree canopy and FireWise building design within the WUI to produce additional tree canopy benefits such as urban heat island mitigation.

Conclusion

South Kohala and North Kona’s dynamic landscape is exposed to various land management goals that influence landscape vulnerability to wildfire. Urban expansion into nonnative grass land cover and the projected warmer, drier climate increases WUI wildfire risk for South Kohala and North Kona. This projected urban expansion will perpetuate and intensify the wildfire cycle driven by nonnative grasses, humans, and land cover change (Hawbaker et al., 2017; Trauernicht et al., 2015). Due to the strong human influence on wildfire behavior in South Kohala and North Kona, there is a great need for state, county, and district land management plans and goals to reflect the spatial relationship between land cover change and wildfire risk. Projected urban expansion provides an opportunity to restore and utilize native tree species canopies to mitigate wildfire risk in the WUI in tandem with land management practices that promote county level environmental goals to sustain ecological, social, and cultural land values for future generations.

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Appendix A
List of tables and figures

Table A1 Degree to which county plans/policies include land management themes related to fire risk and urban expansion or land cover change. Green (✓) indicates acknowledgement/ presence of the theme in plan, yellow (/) indicates vague inclusion, and red (--) indicates absence of the theme. Plans in brown are those adopted by ordinances, bestowing the force of law on these plans.

Management Plans/Policies

Themes in Management	CWPP-Northwest Hawai'i Island	CWPP-North Kona	County of Hawai'i Climate Action Plan	County of Hawai'i Multi-Hazard Mitigation Plan	State of Hawai'i 2018 Hazard Mitigation Plan	South Kohala Community Development Plan	Kona Community Development Plan	County of Hawai'i General Plan	
	Urban expansion in the WUI or near	--	--	--	✓	✓	✓	✓	✓
	Wildfire risk presence	✓	✓	✓	✓	✓	✓	✓	✓
	Wildfire exacerbated by land cover change and or/climate change	✓	✓	✓	✓	✓	✓	--	--
	Wildfire adaptation initiatives (Firewise, fuels mitigation)	✓	✓	--	✓	✓	✓	✓	--
	Wildfire mitigation initiatives (carbon sinks, fuels conversion, green breaks)	✓	✓	✓	✓	✓	✓	✓	--
	Key actions and initiatives for fire resilient landscapes	✓	✓	--	✓	✓	✓	/	--

Table A2 Degree to which plans with environmental goals support or include wildfire mitigation and adaption techniques and if they are mutually exclusive. Dark blue (i) indicates the plan has the specified goal independent as a means of fire mitigation and adaption, light blue (+) indicates that the goal exists as a means of fire mitigation and adaptation, and red (-) indicates that the plan does not include the specified goal. Management Plans in black are at the county level and those in blue are at the state level.

Management Plans/Policies

Environmental Goals	CWPP-Northwest Hawai'i Island	CWPP-North Kona	Vegetation Management Rapid Mapping Assessment and Collaborative Action Planning Hawai'i Island Report	County of Hawai'i Climate Action Plan	County of Hawai'i General Plan	Hawai'i Forest Action Plan	Hawai'i 2050 Sustainability Plan	Hawai'i Highways Climate Adaptation Action Plan	
	Tree Planting/canopy goals	-	(+)	(+)	i	i	i	-	-
	Invasive species removal	(+)	(+)	(+)	-	-	i	i	-
	Native species planting	(+)	(+)	(+)	i	i	i	i	-
	Fire risk reduction, adaptation, or mitigation	(+)	(+)	(+)	-	-	(+)	-	(+)

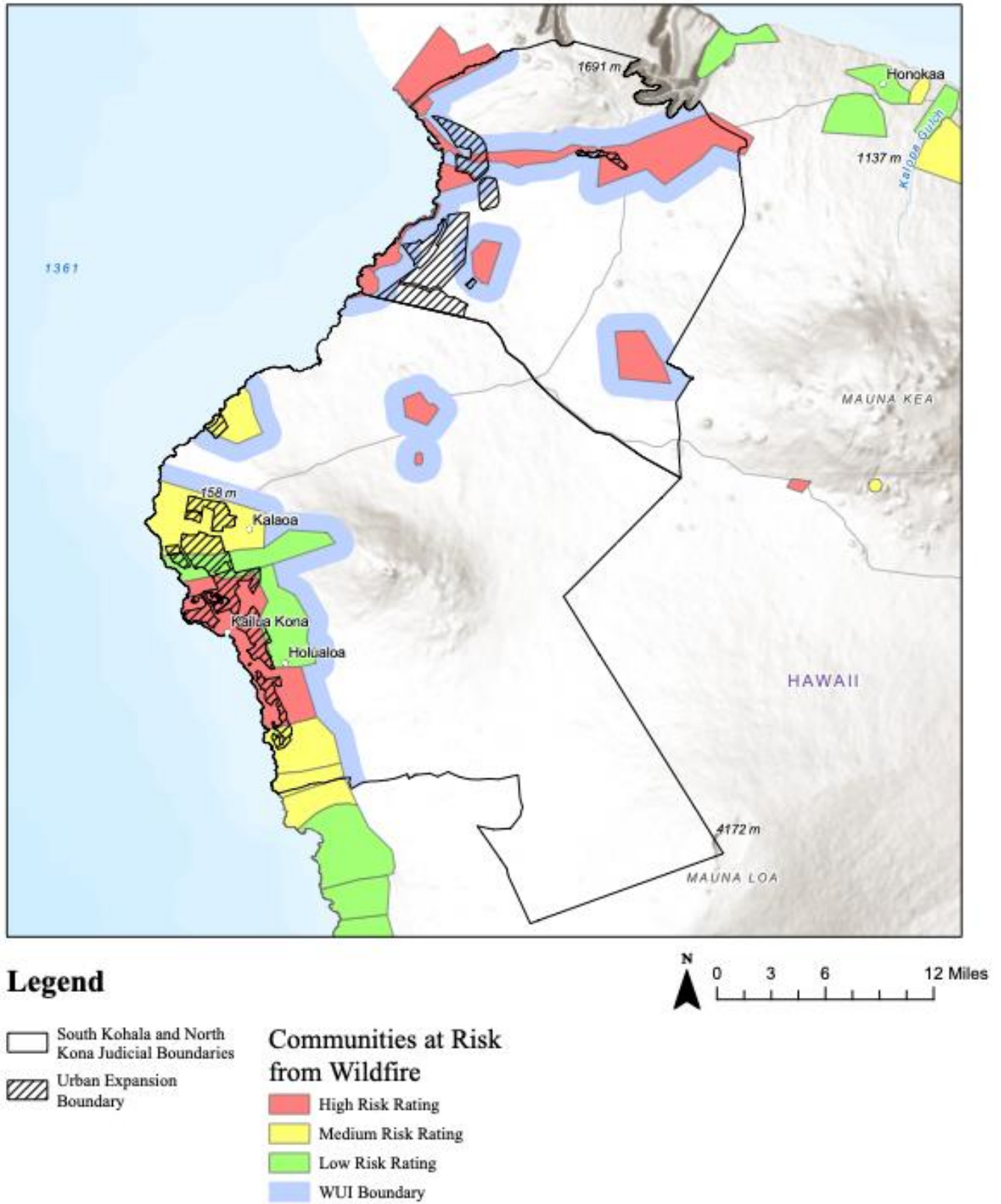
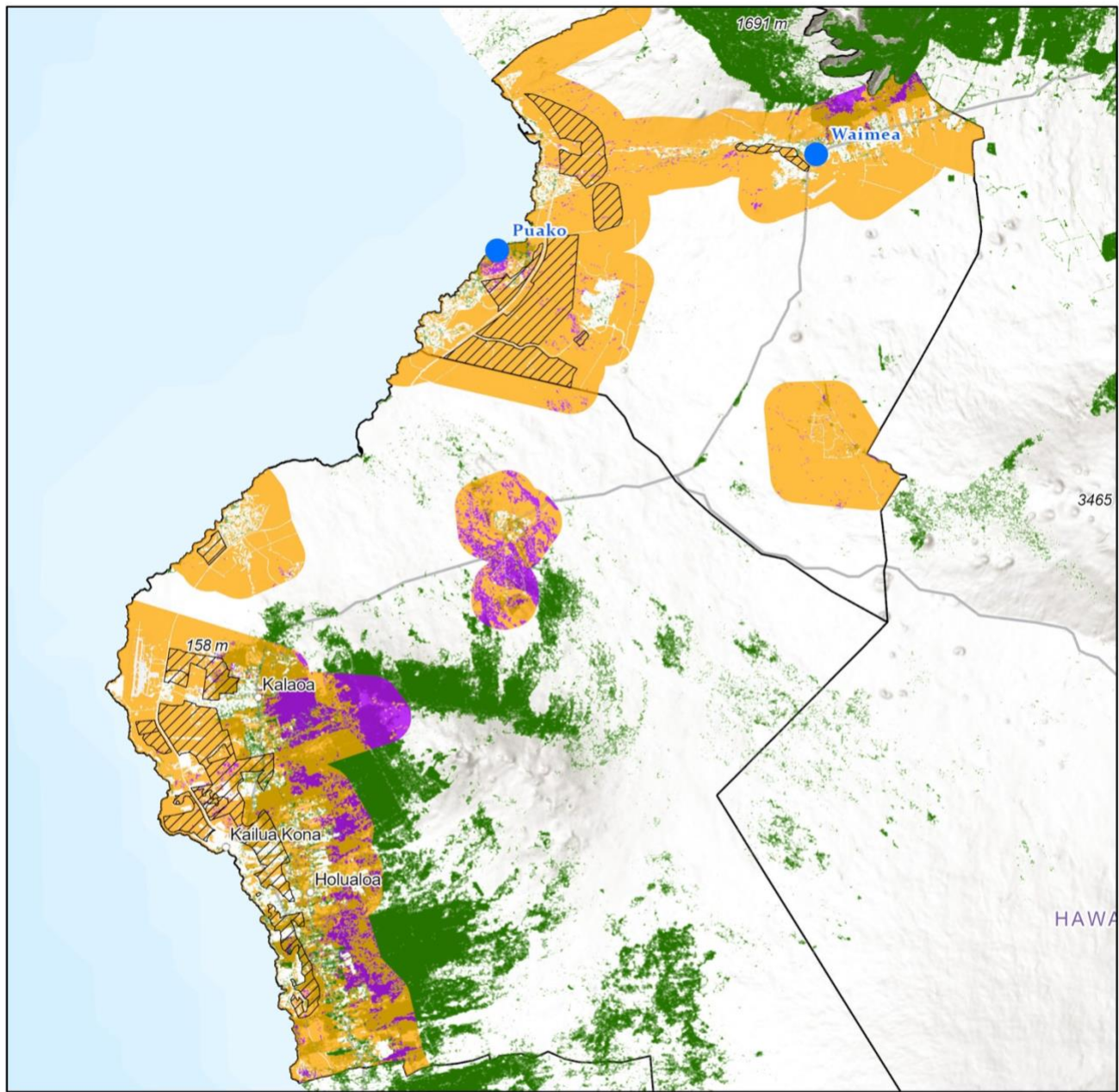


Figure A1 Existing communities at risk from wildfire (in red, yellow, and green), their wildfire risk rating and WUI boundaries, and projected urban expansion from the LUPAG in South Kohala and North Kona, Hawai'i.



Legend

- Native Species Land Cover
- Alien and Bare Land Cover
- Hawaii 2020 Tree Canopy
- Urban Expansion Boundary
- South Kohala and North Kona Judicial Boundaries

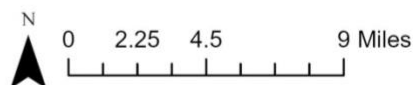
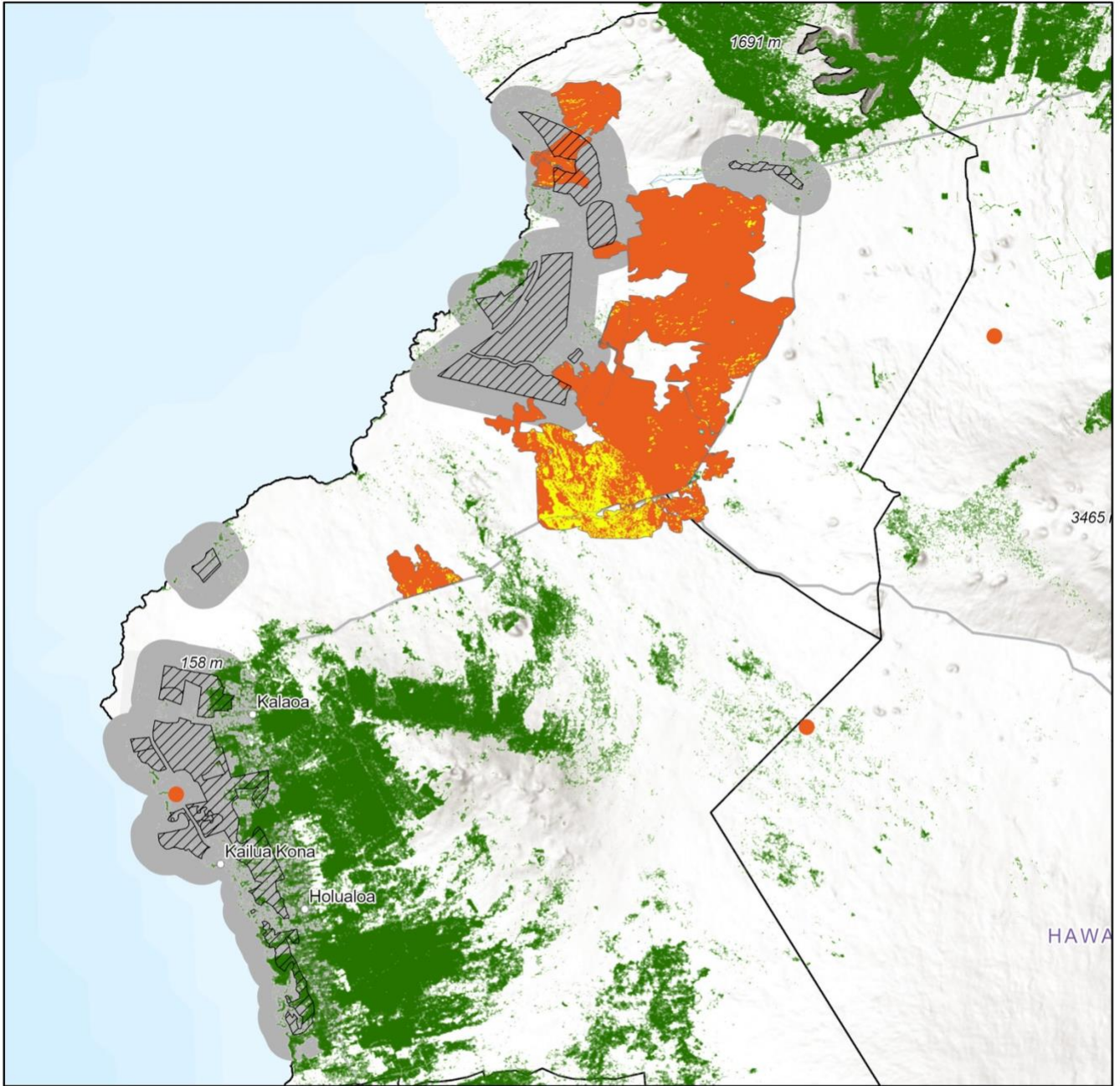


Figure A2 Land cover types and tree canopy in existing communities at risk from wildfire and projected urban expansion WUI boundaries in South Kohala and North Kona, Hawai'i.



Legend

- | | | |
|------------------------------|---|-----------------------------------|
| Hawaii 2020 Tree Canopy | Urban Expansion Boundary | Alien Species and Bare Land Cover |
| Urban Expansion WUI Boundary | South Kohala and North Kona Judicial Boundaries | Native Species Land Cover |
| | Low Intensity Developed or Alien Tree Plantation Land Cover | |

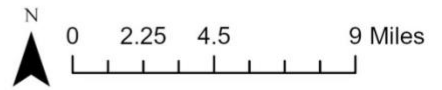


Figure A3 Land cover of historically burned areas and fire perimeters in proximity to projected urban expansion for South Kohala and North Kona, Hawai'i.

APPENDIX B*List of state, county, and district plans*

Table B1- List of county, state, and district plans reviewed for Table A1

Level of Government	Name of Plan
State	State of Hawai‘i 2018 Hazard Mitigation Plan
County	County of Hawai‘i General Plan
	County of Hawai‘i Climate Action Plan
	County of Hawai‘i Multi-Hazard Mitigation Plan
District	Community Wildfire Protection Plan for Northwest Hawai‘i Island
	Community Wildfire Protection Plan for North Kona
	Kona Community Development Plan
	South Kohala Community Development Plan

Table B2- List of county, state, and district plans reviewed for Table A2

Level of Government	Name of Plan
State	Hawai‘i Forest Action Plan
	Hawai‘i 2050 Sustainability Plan
	Hawai‘i Highways Climate Adaptation Action Plan
County	County of Hawai‘i General Plan
	County of Hawai‘i Climate Action Plan
	Vegetation Management Rapid Mapping Assessment and Collaborative Action Planning Hawai‘i Island Report
District	Community Wildfire Protection Plan for Northwest Hawai‘i Island
	Community Wildfire Protection Plan for North Kona

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Data Portals

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