How does forest fire impact above ground tree biomass in Iceland? - a study of fire effects

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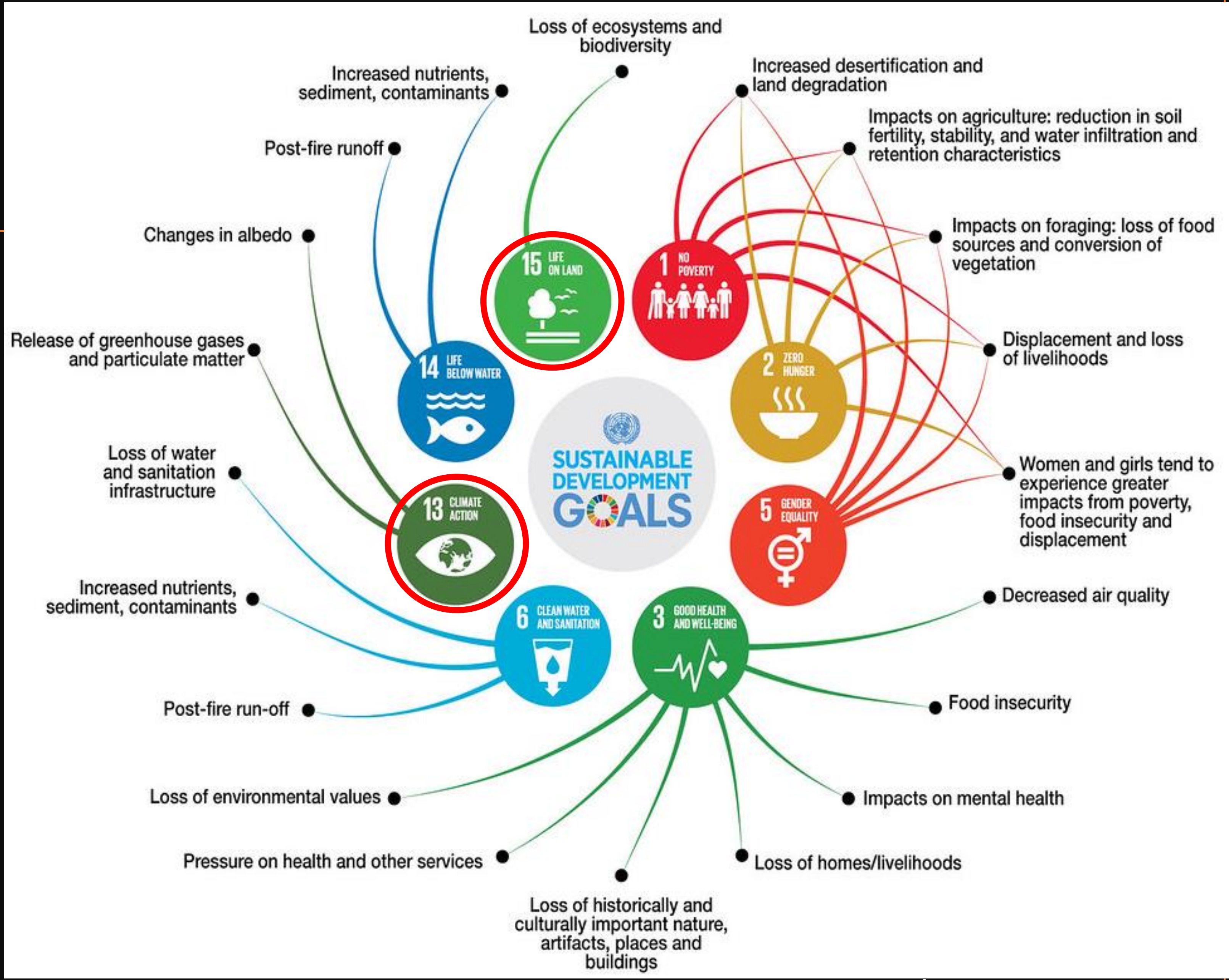
MSc Forestry dissertation presentation - 21st March ‘24

USDA, 2013

Research importance

Global increase uncontrollable Wildfires/FF's : diverse & devasting effects

- ➢ **Fire effects studies: readiness**
- Increase **understanding** of **fire** in the **landscape:**
  - **Factors of fire** - carrying fuels, topography, climate & weather
  - **Fire ecology** – heat processes
  - **Fire regime** - occurrence space/time
  - **Post-fire recovery** (Bennet et al., 2010)
- **Inform management decisions: reduce fire risk** severity **local scale**



GRID-Arendal/Studio Atlantis, 2021

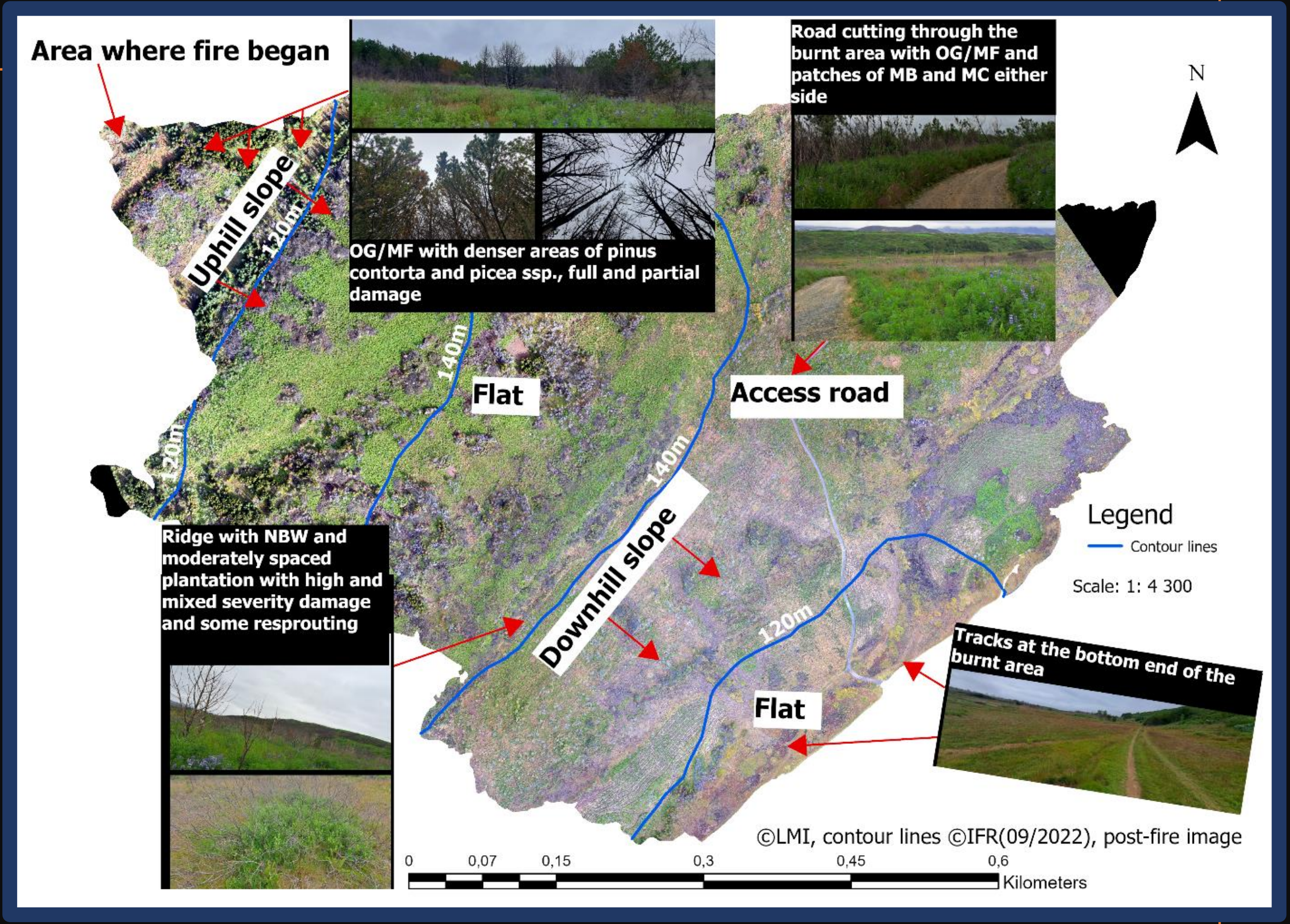
What's the Icelandic situation?

- Management focus: intervention & response
- Documented since 2006 (IINH): limited occurrence (limited research opportunities)
- **Increased risk**: greening, afforestation, reduced grazing, warming

Working on Fire, no date

What's the Icelandic situation?

➢ <u>Research opportunity:</u> Collect Icelandic fire data for improved FF reporting, research & management:
  - Increase readiness
  - UN requirements
  - Icelandic Environment Agency



FF Heiðmörk (2021) - affected area: 56.46 ha of mixed density broadleaves, conifers, native birch woodland & open land

Fire effects study: Heiðmörk

- Study aim: evaluate & analyse how fire effects above ground tree biomass
- Data collected autumn ’22: Heiðmörk
- 2 part analysis:
- ❑Part 1, emissions estimates: Icelandic single tree biomass equations
- ❑Part 2, factors & impacts analysis: Logistic regression modelling - test influence of 8 characteristics of fuels AND topography on tree burn damage & mortality

Post-fire image, taken summer 2023

Part 2 - research hypotheses

1. Tree burn damage increases with:	2. Tree mortality increases with:
1.1 Increased plant litter	**2.1 Increased plant litter**
1.2 Increased vegetation cover	2.2 Increased vegetation cover
1.3 Decreased bark thickness	2.3 Decreased bark thickness
1.4 Decreased tree height	**2.4 Decreased tree height**
1.5 Decreased stand age	2.5 Decreased stand age
1.6 Coniferous species	2.6 Coniferous species
1.7 South and south-east facing slopes	2.7 South and south-east facing slopes
1.8 Increased slope gradient	**2.8 Increased slope gradient**

Methods and materials

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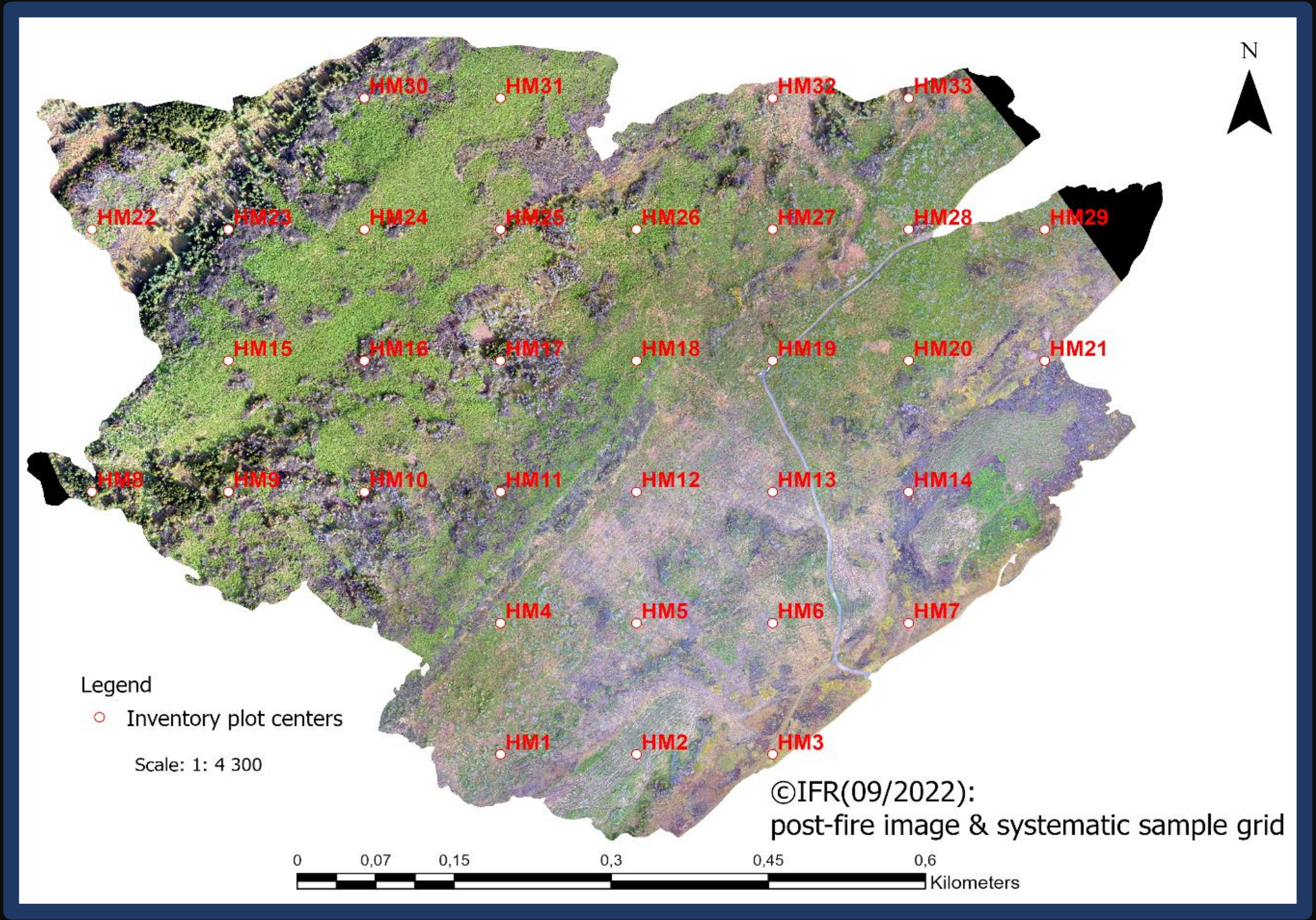
Study design

STUDY DESIGN

- **Type:** empirical
- **Sampling:** systematic sampling: representivity (32 100m2 plots)
- **Data types:**
- Primary: drone imagery, site inventory & tree survey (223 trees)
- Secondary: aerial images, in pers.com & weather data



Map with systematic plot scheme (data sources: IFR, 2022; image: Kjartansson et al., 2022)

Data collection

DATA COLLECTION – AUTUMN '22

- **Parts 1&2: IFI inventory:**
- Trees: DBH(mm), height(m)
- Surface vegetation: class & cover etc.
- **Part 2 - Tree survey:**
- Factors, heat processes & impacts

Pole with reflector held by Osvaldo Borello, measuring pinus contorta

Detecting trees with the lazer range finder

Entering data and observations into the field computer with Bjarki Þor Kjartansson

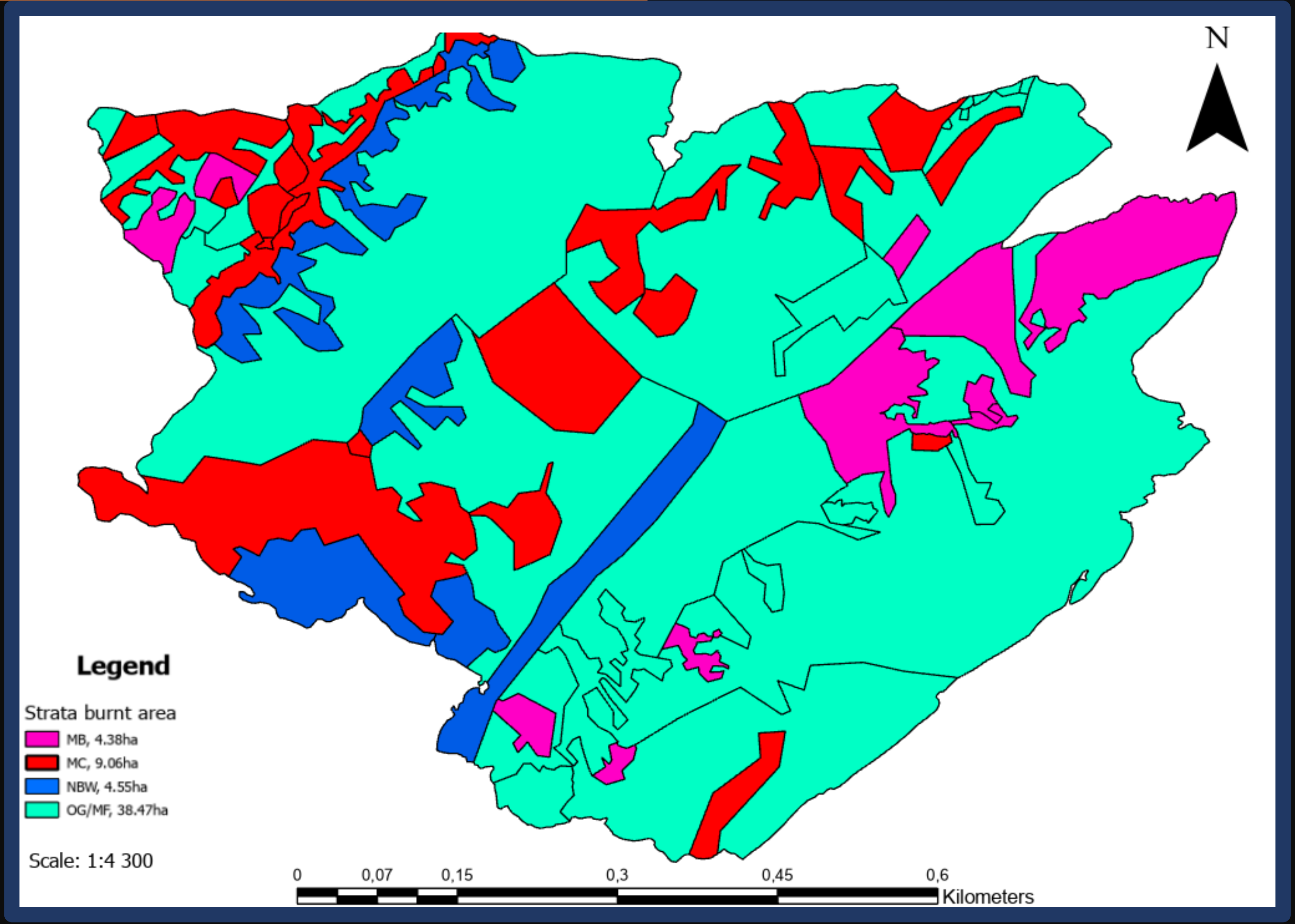
Plot center marker

Field work autumn, '22. Image top right: Reykjavik forestry association (2022)

Post-stratification

POST INVENTORY - STRATIFICATION

- Part 1: post-stratification: scaling biomass estimations
- OG/MF: 38.47 ha
- MB: 4.38 ha
- MC: 9.06 ha
- NBW: 4.55 ha



Post-stratification burnt area (data sources: IFR, 2022)

Analysis & statistical methods

BIOMASS EQUATIONS & LOGISTIC REGRESSION

- **Part 1: emissions estimates**
- Icelandic single tree biomass equations (Snorrason and Einarsson, 2006)
- Tree, plot & site level
- Conversion factors
- **Part 2: factors & impacts**
- Data preparation
- Summary statistics
- *k*-fold cross validation with multiple logistic regression model (LRM)
- R studio & Excel

Predictor variables	Variable levels
1. Species (categorical) 2. Height (m) (numeric) 3. DBH (mm) (numeric) 4. Stand age (mm) (numeric) 5. Slope angle (numeric) 6. Slope face (categorical) 7. Vegetation cover (categorical) 8. Plant litter (categorical) Other predictor variables (not included in the LRM) • Ladder fuels (categorical) • DKH (mm) (numeric)	1. broadleaf, conifer 7. low to moderate, high 8. plant litter, no litter
Outcome variables	**Levels**
1. Tree status (categorical) 2. Burn damage (categorical) Other outcome variables (not included in the LRM): • Heat transfer & reaction (categorical) • Regeneration type (categorical) • Soil preparation (categorical)	1. 0 = dead, 1 = alive 2. 0 = no damage, 1 = moderate to high

Part 1 - Results & discussion

USDA, 2013

Results part 1:
Above ground tree biomass loss & emissions

Tree biomass and necromass (kg) by species group

Species group (N)	Populus trichocarpa, N = 1	Betula pubescens & Sorbus, N = 58	Salix myrsinifolia &alaxensis, N = 32	Pinus contorta, N = 89	Larix sibirica, N = 2	Picea glauca& sitchensis, N = 41
Biomass (kg)						
Sum	-	463.13	731.20	1431.24	37.16	315.62
Mean ±(SD)	-	21.05 ±(27.93)	30.47 ±(17.67)	26.02 ±(26.86)	18.58 ±(20.79)	19.73 ±(18.61)
±SE	-	±5.95	±3.61	±3.62	±14.70	±4.65
Necromass (kg)						
Sum	1.66	146.00	99.33	114.21	-	42.70
Mean ±(SD)	1.66 -	4.06 ±(7.44)	12.42 ±(14.96)	3.36 ±(4.90)	-	1.71 ±(1.81)
±SE	-	±1.24	±5.29	±0.84	-	±0.36

(N)number of trees/species group
Sum of treeAGB/necromass (kg) by species group, mean (sum of treeAGB/necromass (kg) by species group), ±(SD), ±SE = standard deviation of the sample mean and standard error

Tree biomass&necromass/ ssp. group

Species groups in sample:

- Low presence: *Populus trichocarpa* & *Larix sibirica*

Biomass equations:

- ***Pinus contorta* highest amount of biomass**
- ***Betula pubescens* & *Sorbus* highest amount of necromass**
- *Salix myrsinifolia & alaxensis* highest mean biomass and necromass

Results part 1:
Above ground tree biomass loss & emissions

±SE of post stratification classification

Strata	N°plots	ha	±SE
MB	9	4.38	±0.08
MC	13	9.06	±0.08
NBW	1	4.55	±0.03
OG/MF	9	38.47	±0.08

Post-stratification:

- 1 plot predominant stratum NBW
- MB, MC & OG/MF equally represented

***Sum** tree biomass, carbon CO_2-e and **emissions, by stratum** (t)*

Strata	MC	MB	NBW	OG/MF
Tree biomass	120.90	60.53	-	-
Tree necromass	11.13	11.84	0.46	-
Tree Carbon	60.45	30.26	-	-
Tree Carbon loss	5.56	5.92	0.23	-
Tree CO_2-e	221.84	111.07	-	-
Tree CO_2-e loss	20.42	21.72	0.83	-
necromass:biomass	0.14	**0.20**	-	-

- **Necromass**:biomass **proportionally higher** in **MB**, 0.20, vs **MC**, 0.14
  - NBW not present in this ratio

Discussion - results part 1: Above ground tree biomass & emissions

Results

- **Estimates obtained**: High/low? Difficult to say
- **Higher** in **MB vs MC**, why is this?

Literature

- **Low compared to other sectors** (Environment Agency, 2022)
- **Conifers more ignitable vs broadleaf** (Steidle, 2019)

Interpretations

- **1st study** to **collect** & **apply data** from **FF** in **Iceland > limited data**
- **>Post-stratification**
- **> Calculation method**: whole tree

Improve estimate reliability

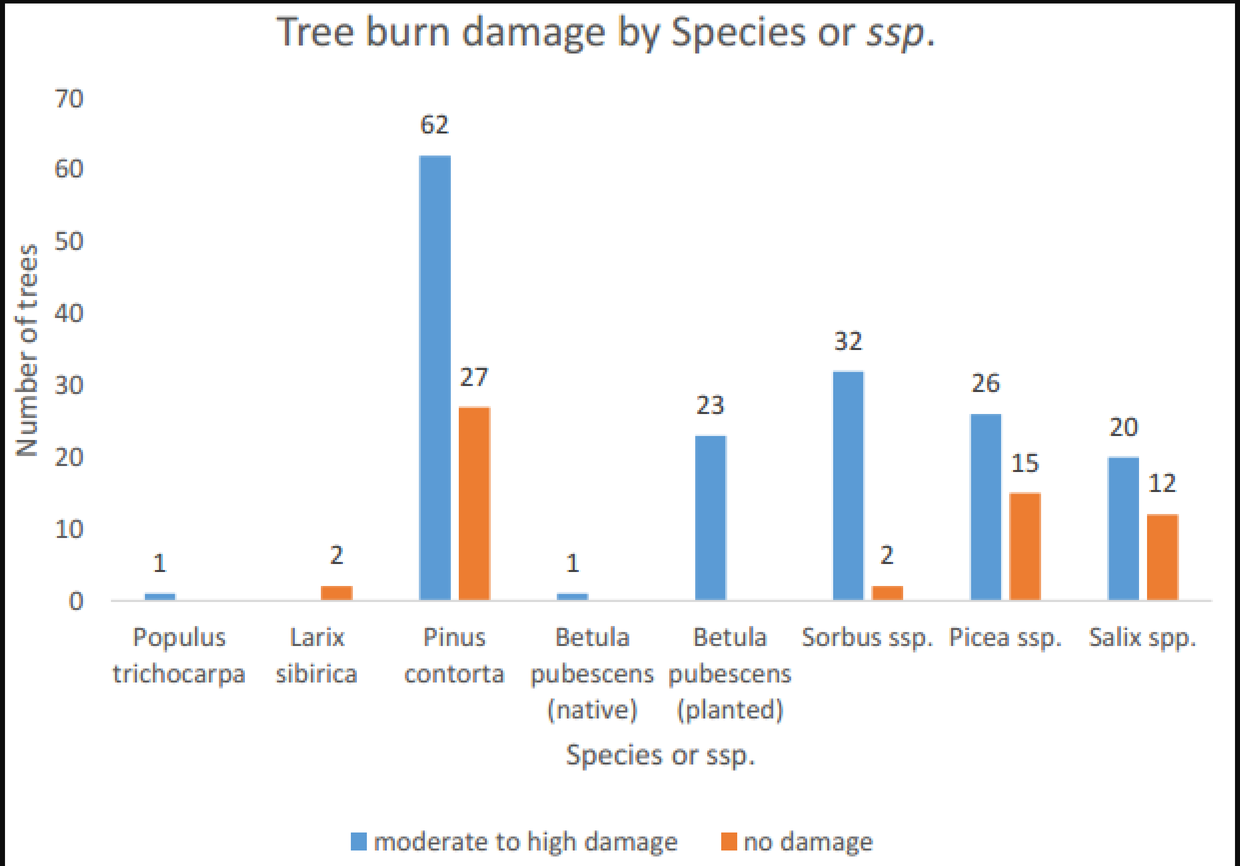
- **Increase & standardise data collection:**
- **Standardise post-stratification:**

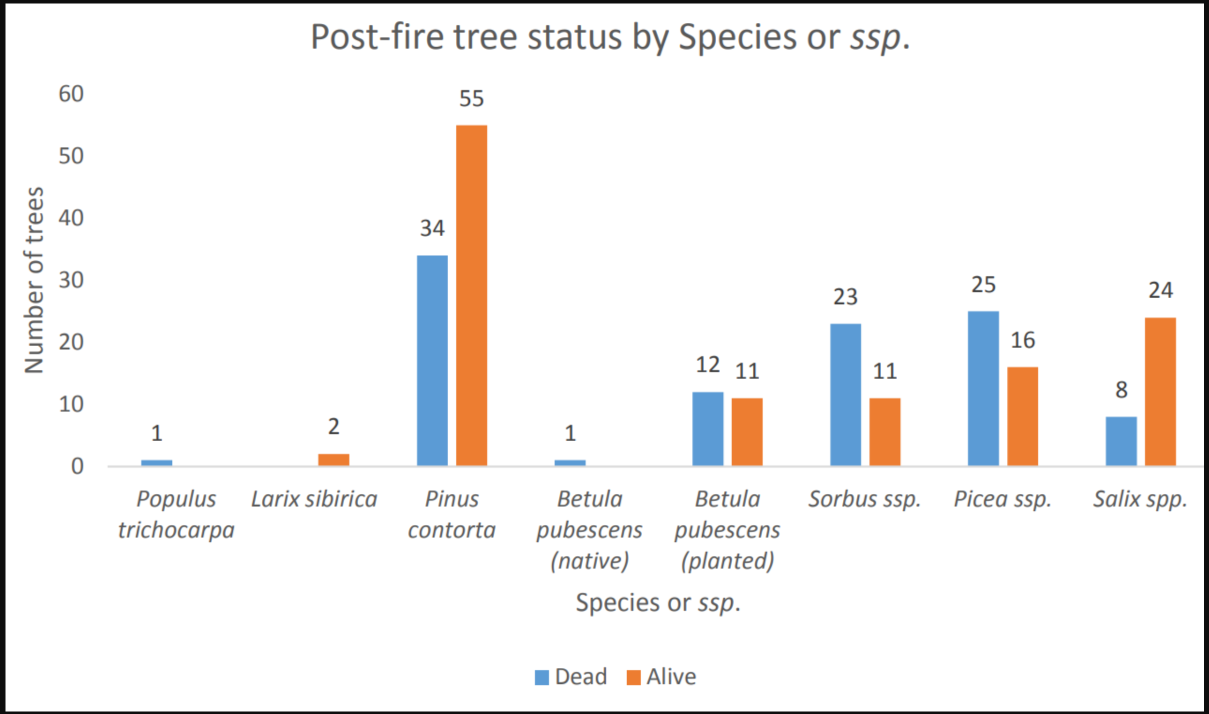
✓ **Study objective: Findings contribute to country specific data collection & reporting**

❑ **Requirement of UN & suggested in Environment Agency report**

Part 2 - Results & discussion

Results part 2 - summary statistics: tree burn damage & mortality





Tree status by species or ssp.

- ❑ Moderate (50-70%) or high damage (70-100%) 74% of trees
- ❑ Almost even split of dead and living trees

Results & discussion part 2.1:
Logistic regression model - tree burn damage

Tree burn damage final model, test data set – significant results

	Estimate	Std. Error	z value	Pr(>|z|)	Wald Test	Odds Ratio	95% CI Lower	95% CI Upper
(Intercept)	-6.260	1.191	-5.256	0.000	-5.256	0.002	0.000	0.020
Height(m)	1.049	0.203	5.166	0.000	5.166	2.854	1.917	4.249
Vegetation Cover: high	-2.762	1.117	-2.472	0.013	-2.472	0.063	0.007	0.564
Slope angle	0.163	0.040	4.107	0.000	4.107	1.178	1.089	1.273

1.2: Increased vegetation cover did not increase damage

Fuel availability/continuity:

- Plots w/ high cover: grassland VS
- Plots low-med cover: ladder fuels

Post fire recolinisation: ground/surface fuels – filling post-fire space?

1:4: Shorter trees were not more damaged than taller trees

- **Uneveness height: damaged trees**
- <ladder fuels: areas of damaged trees

✓ **1.8,** Tree burn damage increases with increased slope gradient - **supported**

Results & discussion part 2.2: Logistic regression - tree mortality

Tree status final model, test data set – significant results

	Estimate	Std. Error	z value	Pr(>|z|)	Wald Test	Odds Ratio	95% CI	
							Lower	Upper
(Intercept)	3.926	0.674	5.823	0.000	5.823	50.725	13.530	190.172
Height(m)	-0.937	0.162	-5.790	0.000	-5.790	0.392	0.285	0.538
Slope angle	-0.062	0.031	-2.001	0.045	-2.001	0.940	0.884	0.999
Plant litter: Nolitter	-1.195	0.486	-2.461	0.014	-2.461	0.303	0.117	0.784

- ✓ **Hypothesis 2.1, tree mortality increases with increased plant litter – supported as expected**
- **Plant litter would have been drier leading up to FF** (no recorded rainfall prior) – fuel moisture is key!

- ✓ **Hypothesis 2.4,** tree mortality increases with decreased tree height **supported -** as **expected –**
- higher **amount** of **ladder fuels** in **areas** of increased tree **mortality**

2.8 Increased **slope gradient** does not increase tree mortality

- **FF began** below **steepest section: limited intensity? Limited mortality**
- Uneveness in tree height + patchy vegetation **mixed severity?**

Results part 2: Research implications

- ✓ **Results contribute to knowledge about how FF impacts trees in Iceland**

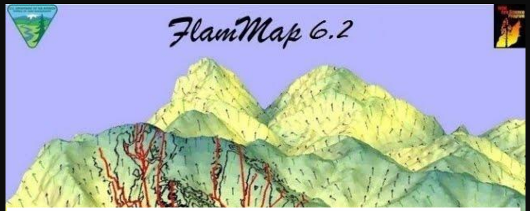
- ✓ **Results provide basis for shaping future for forest fire research, analysis and management in Iceland**

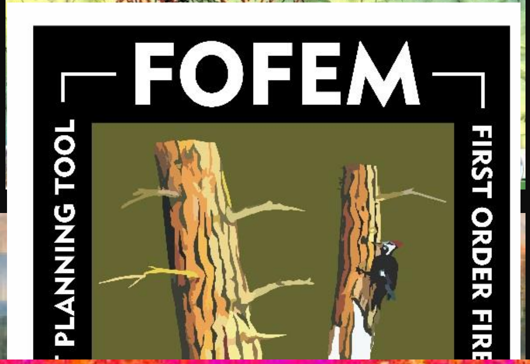
Implications:

- ❑ **Develop country specific integrated fire managemet at landscape scale**

Integrated fire management – some examples

Readiness:





Reduction

Intervention & Response

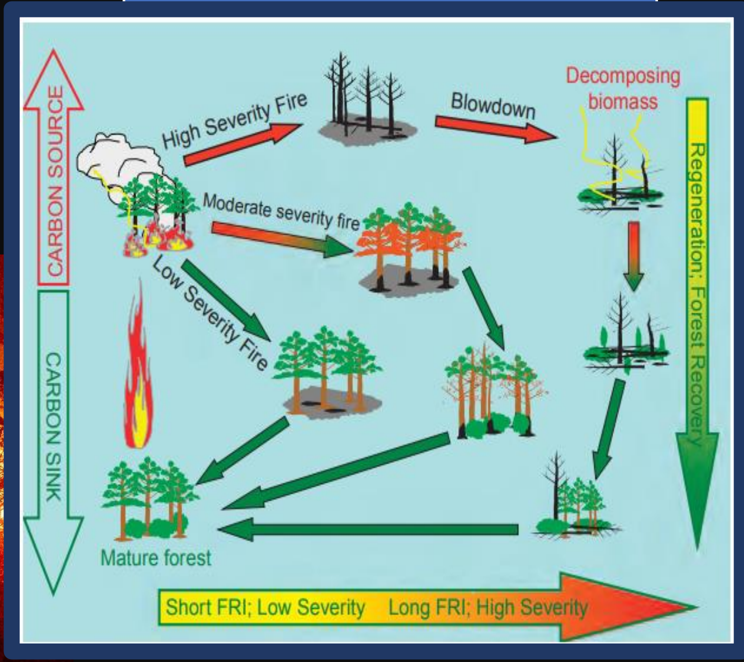
Gróðureldar.is
Forvarnir og fyrstu viðbrögð

(Berger in Ridler, 2021)

Recovery

Monitoring: latent tree mortality, insects, resilience etc.

Rehabilitation: planting, seeding, mechanical



Conclusions


USDA, 2013

Conclusions & recommendations

Results

Part 1 - Emissions:

- Low compared to other sectors
- MB higher emissions than MC

Part 2 – factors & impacts:

- Increased slope angle increased damage
- Shorter trees & litter increased mortality

Research contributions & limitations

First study in Iceland:

>collect & apply field data: estimate FF emissions

>analyse how characteristics of **fuels & topography influence tree damage & mortality**

>Study limitations => partially answered research questions

Recommendations

Anticipate & reduce Icelandic FF risk

> Increase data collection: reliability

> Integrated fire **management:** limit risk/ increase resilience

> Reunite/dedicate **resources** to **coordinate** this **approach**

> Continue research

Thank-you

Land og skógur

SKÓGRÆKTARFÉLAG
REYKJAVÍKUR
Stofnað 1901


USDA, 2013