Forest owners and ecosystem services across Europe

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Incentives for Forest Ecosystem Services in Europe: connecting science, practice and policy

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Other colleagues working on the study: Mario Torralba, Francesco Orsi, Davide Pettenella, Carsten Mann, Davide Geneletti, Tobias Plieninger, Eeva Primmer, Monica Hernandez-Morcillo, Bo Jellesmark Thorsen, Thomas Lundhede, Lasse Loft, Sven Wunder, Georg Winkel

INTRODUCTION

FES Mapping – a lot is already done, but…

….is difficult to map them all

… is difficult to compare them

… and there is lack of information of their income and profitability

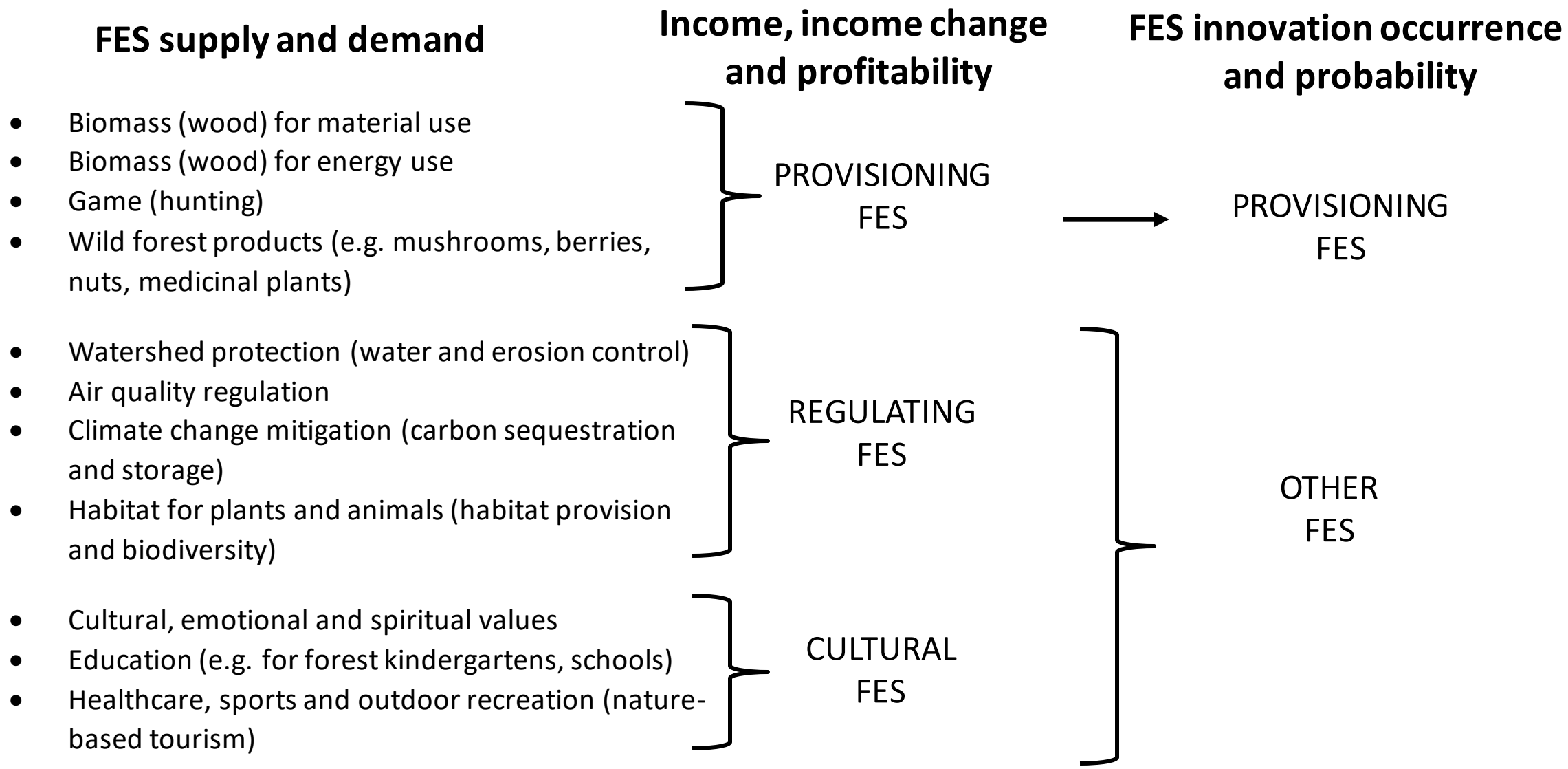
… and there is lack of information of FES-related innovations

RQ: How are forest ecosystem services (FES) distributed across Europe?

DEPENDENT VARIABLES:

- Supply and demand (for 11 FES)
- Income, change of income and profitability (for 3 groups of FES)
- Occurrence of FES-related innovations (provisioning and other FES)

DEPENDENT VARIABLES



PRIMARY DATA COLLECTION

Data collected through surveys, targeting forest owners and managers

1. SINCERE survey (‘top-down’), distributed through CEPF, EUSTAFOR, ELO, FOREXT and FECOF
2. CLEARING-HOUSE (household survey), focused on urban forests

Answers provided with a reference to a certain forest (‘clicked on a map’)

Different sample sized used for different analyzes (500 – 2500)

TASK

Objective – extrapolate the survey's findings to entire Europe

Proposition

demand/supply, income/profitability and FES innovations can be explained by forest characteristics (e.g. growing stock, increment, tree species, distance from the city, protection status, etc.)

Survey data on FES (with point-location)

GIS data on Europe's forests (1 x 1 km grid)

Keras / Tensorflow (Google's machine learning)

FES data on Europe's forests (1 x 1 km grid)

Estimation fit (0-1 range)

Supply, demand, income, profitability: MAE ≈ 0.15 / 0.17

Wood and other innovations: binary accuracy 0.94 / 0.91

SECONDARY (GIS) DATA – INDEPENDENT VARIABLES

- Above and below-ground biomass
- Above and below-ground carbon
- Above-ground biomass
- Above-ground carbon
- Travel time to closest city 2000
- Population density
- Reference evapotranspiration
- Growing stock volume
- Forest biomass increment
- Average annual rainfall
- Average slope

- Soil bearing capacity
- travel time to cities 2015
- terrain ruggedness
- Forest ownership
- Natura 2000 Sites (SPA, SCI, SPA + SCI)
- Country (binary)
- Percentage share of tree specie (20)
- Dominant tree specie (0/1 for 20)

- **Above and below-ground biomass > 0 as forest criterion**
- **Only full data used on 1 x 1 km grid**
- **Covers 1.45 mil km^2, or 85% of European forest area (no Russia)**

WHAT ANALYZES HAVE WE DONE AND WHY?

1. To see the distributions of results
    1. By values (histograms)
    2. By geography (maps)

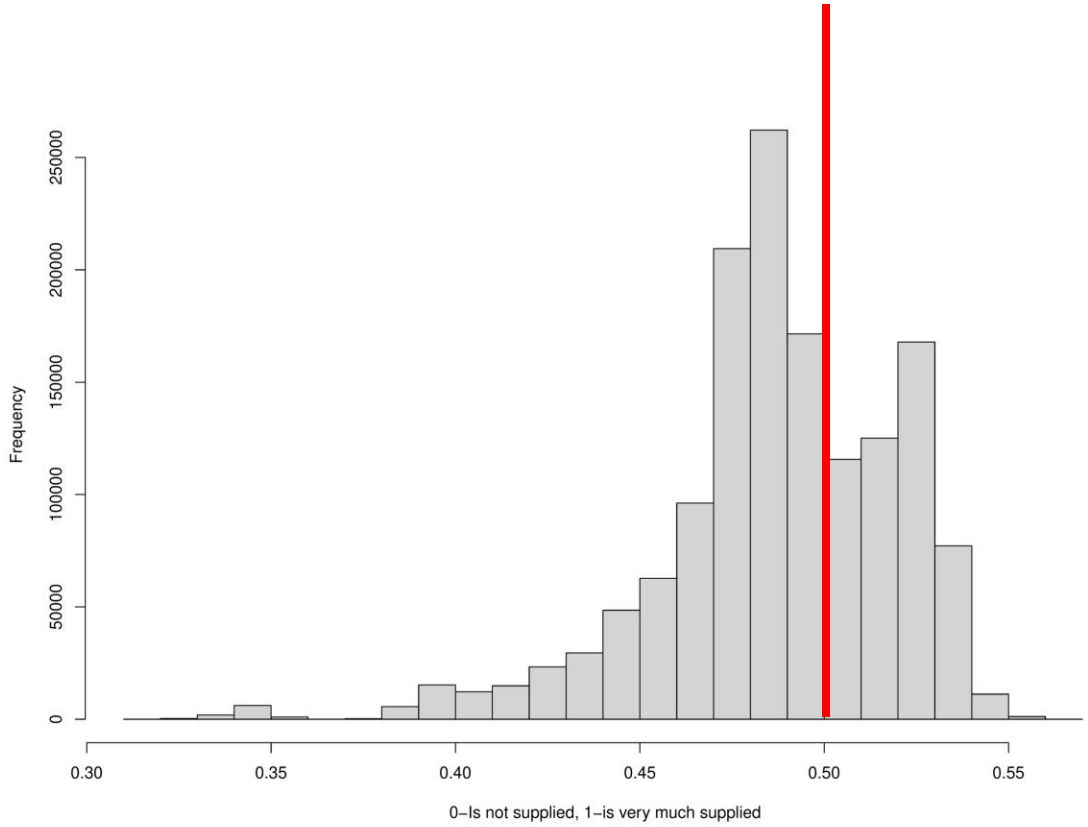
2. To see can dependent variables be somehow grouped (factor analysis)

3. To see can cases (forest point-locations) be somehow grouped
    1. cluster analysis - to see the groups
    2. ANOVA - to see if there are significant differences between the groups

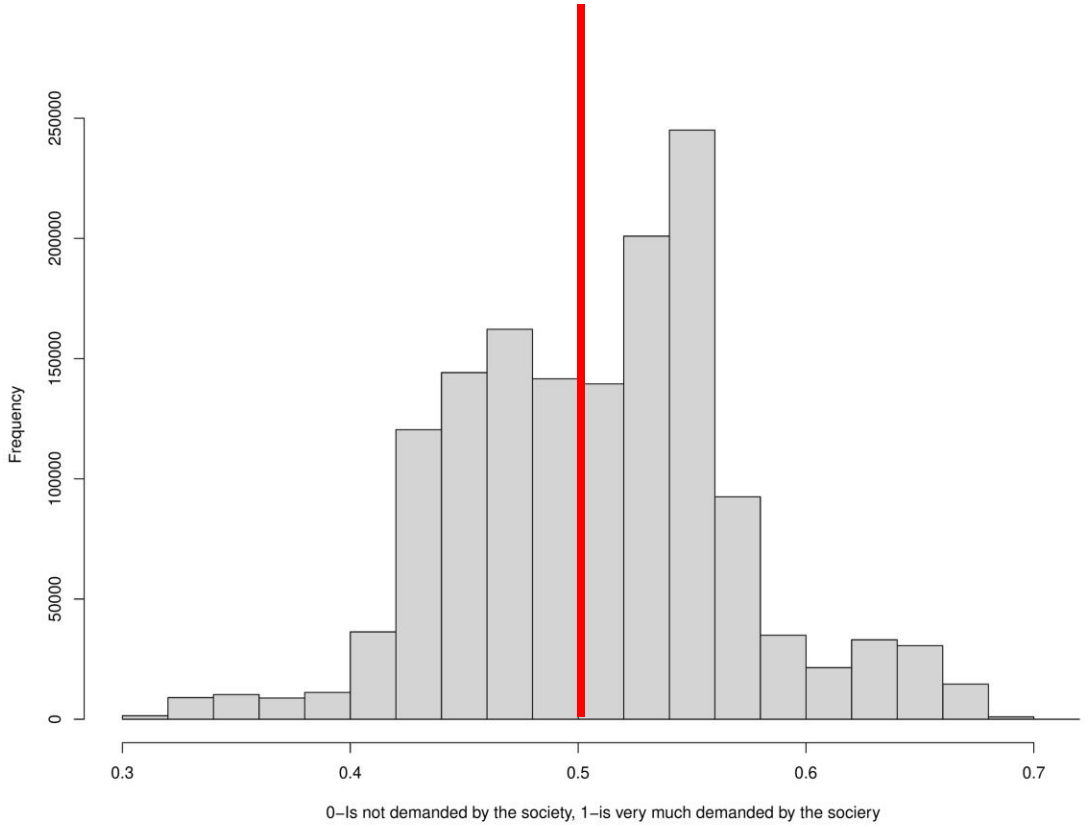
(SOME PRELIMINARY) RESULTS

HISTOGRAM - NWFPs

SUPPLY



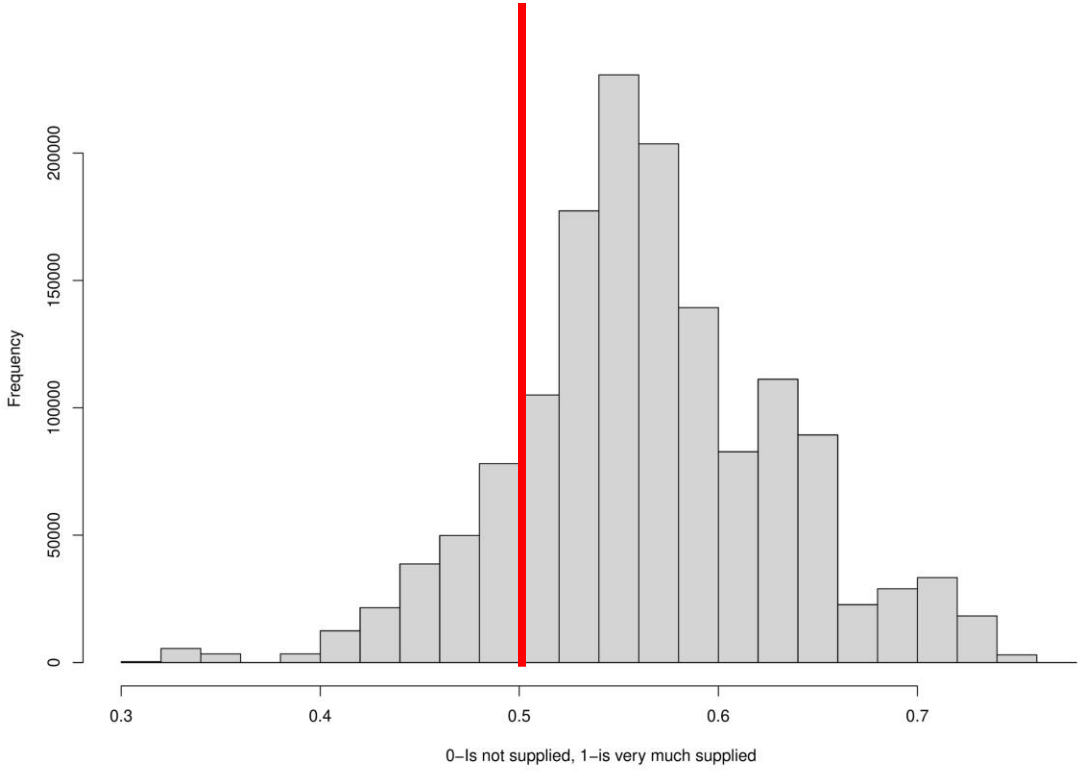
DEMAND



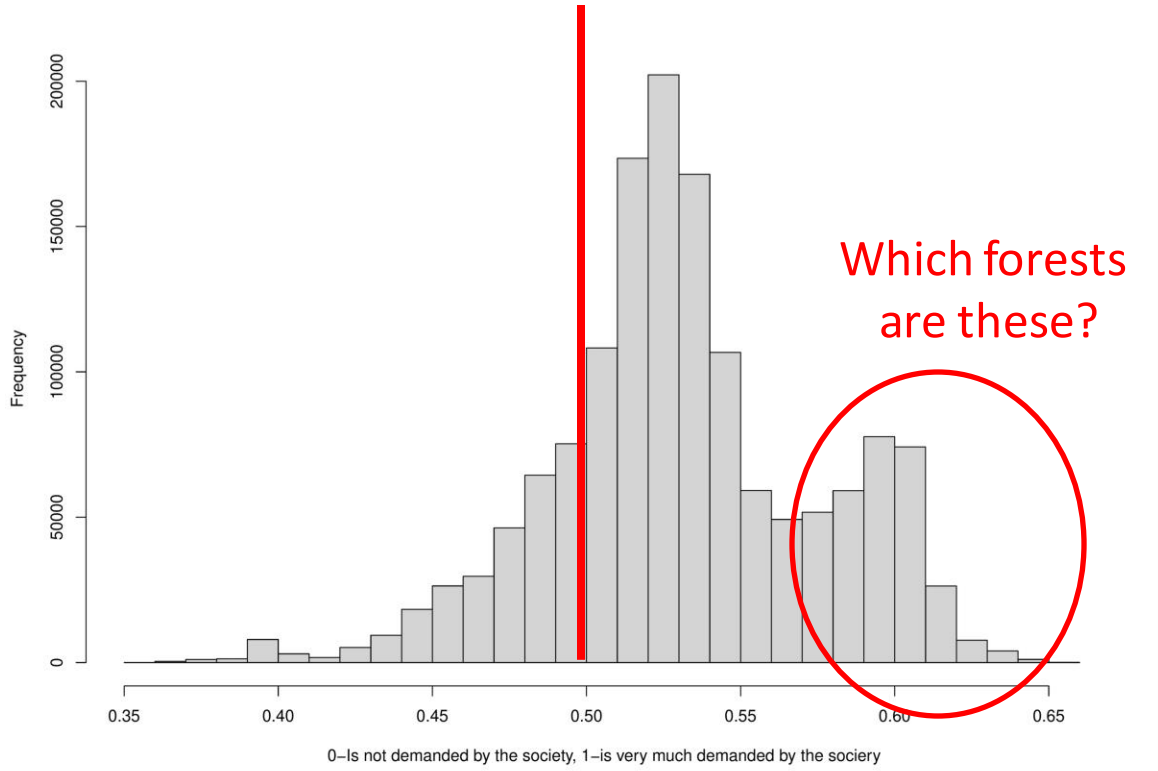
NWFPs are more demanded than supplied

HISTOGRAM – CULTURAL FES

SUPPLY



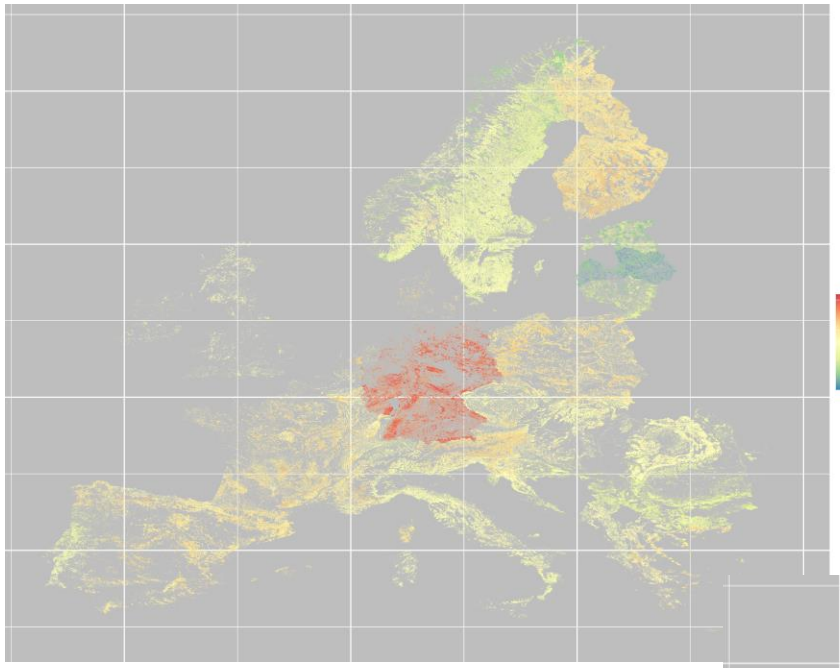
DEMAND



Supply and demand for cultural FES are balanced

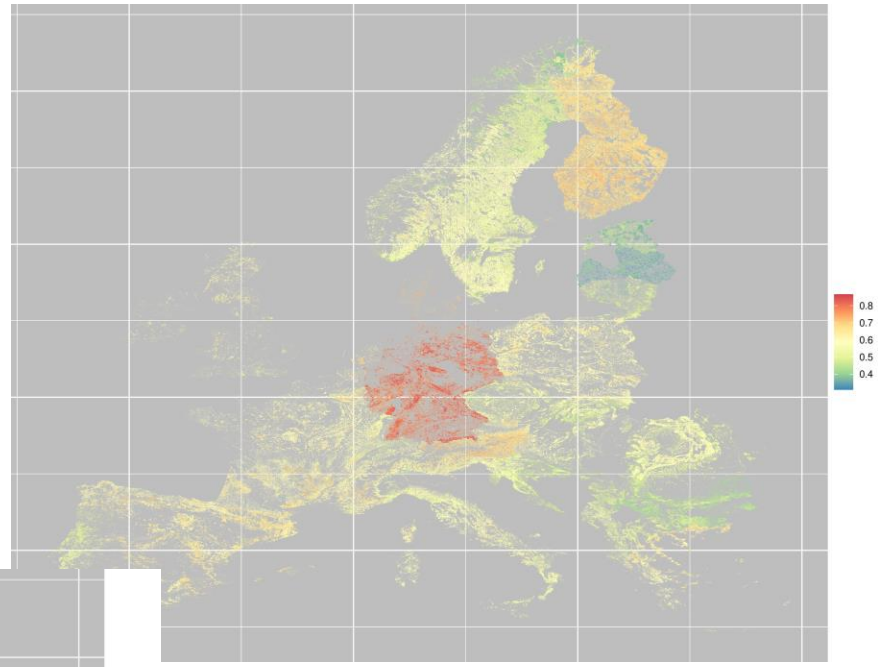
MAP – Healthcare, sports and outdoor recreation (nature-based tourism)

SUPPLY

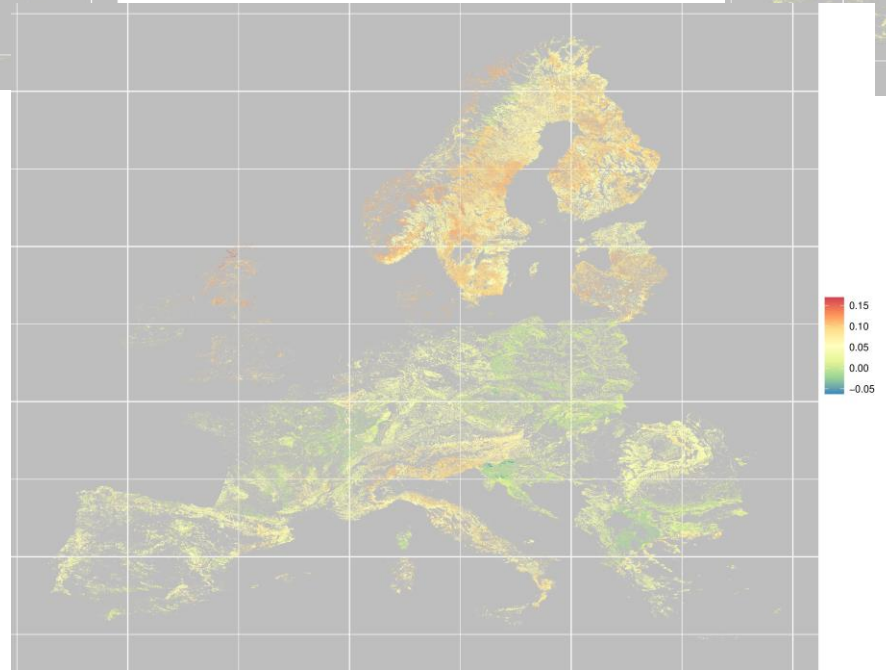


Very similar distribution

DEMAND

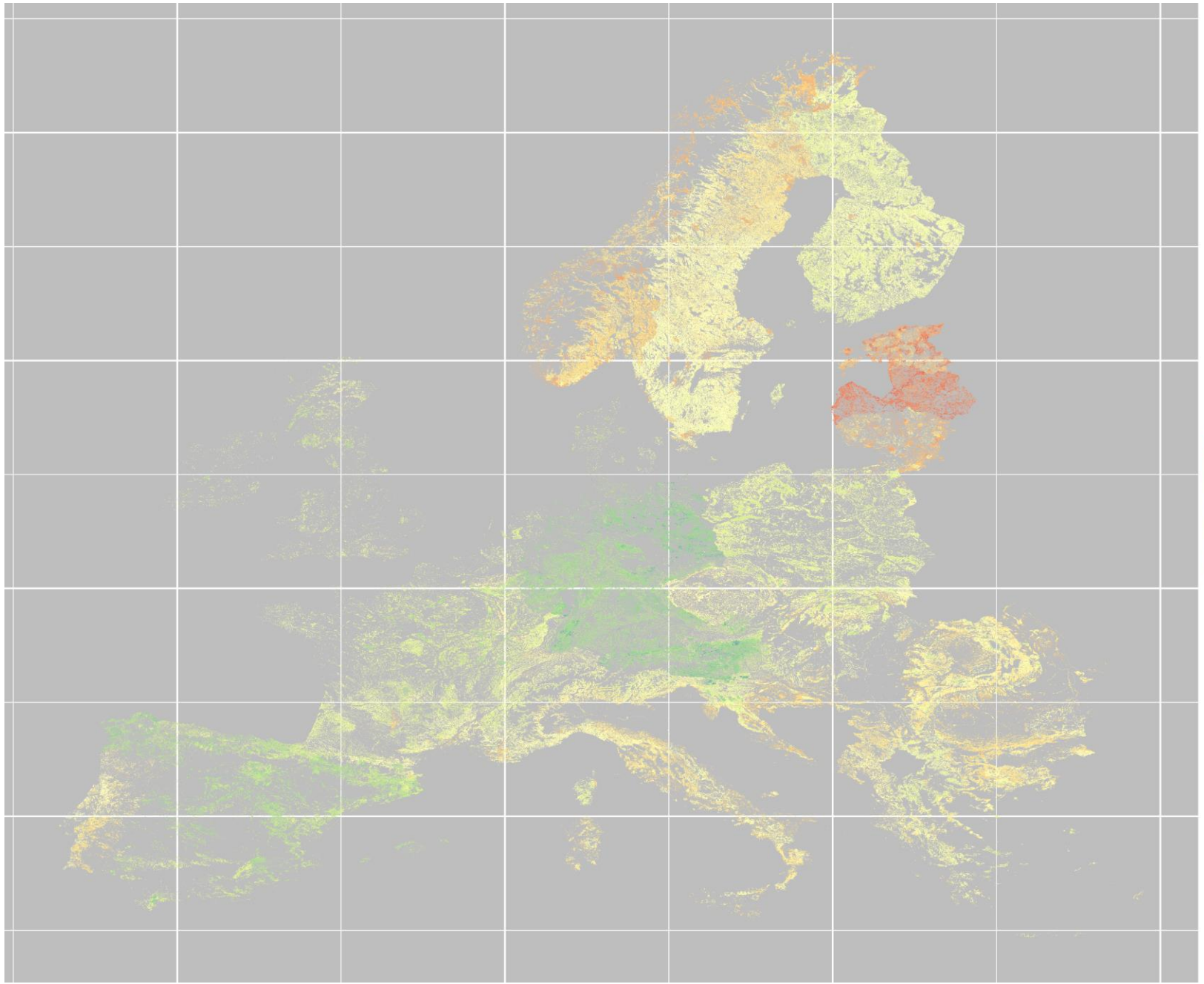


DEMAND - SUPPLY

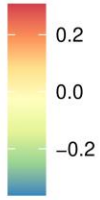


More needed in
North and South

MAP – regulating FES demand minus supply



More need for regulating FES in the North, East and South



MAP – clustering of forests based on demand minus supply

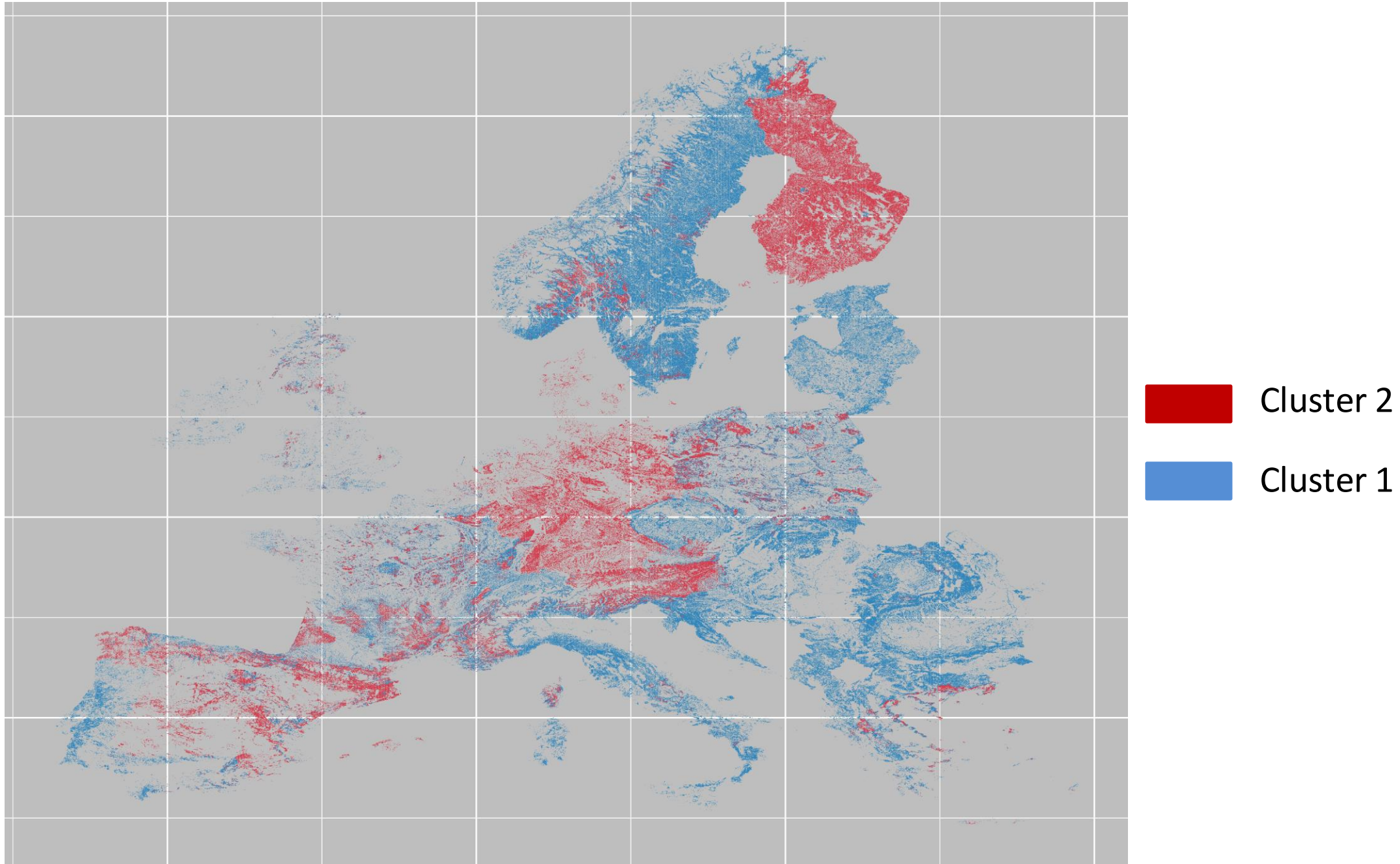
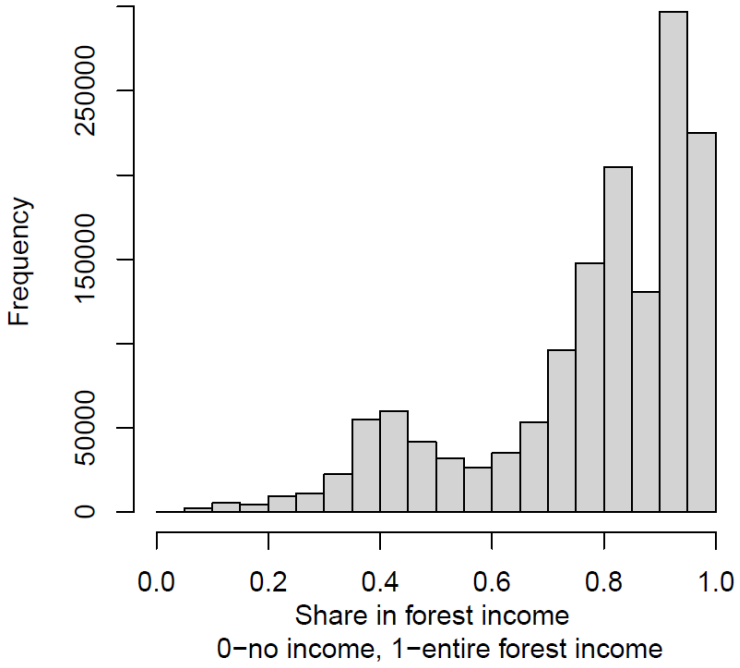


Table - clustering of forests based on demand minus supply

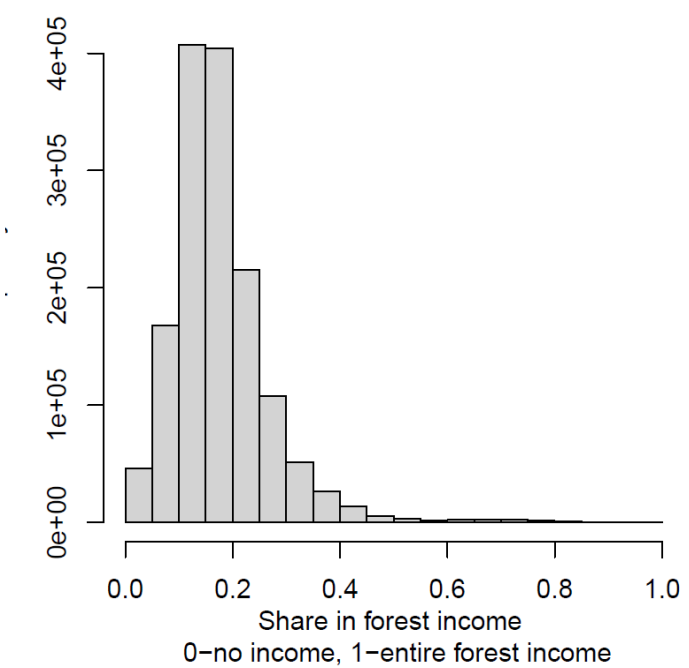
	CLUSTER 1 (807 042cases) Has sig. higher values for	CLUSTER 2 (651 899 cases) Has sig. higher values for
Dependent variables		**All FES supply (μ +26%) and demand (μ +20%)**
Geography	Norway, Sweden, South-Eastern Europe, half of France, Baltic countries, Italy, Portugal	Finland, Poland, Germany, north-west Spain, half of France
GIS forest data	Population density, Evapotranspiration, Increment, rainfall, Slope, Closer to a city, Terrain ruggedness,	Carbon and biomass, Growing stock volume,
Tree species	broadleaves	conifers

HISTOGRAM - INCOME FROM FES

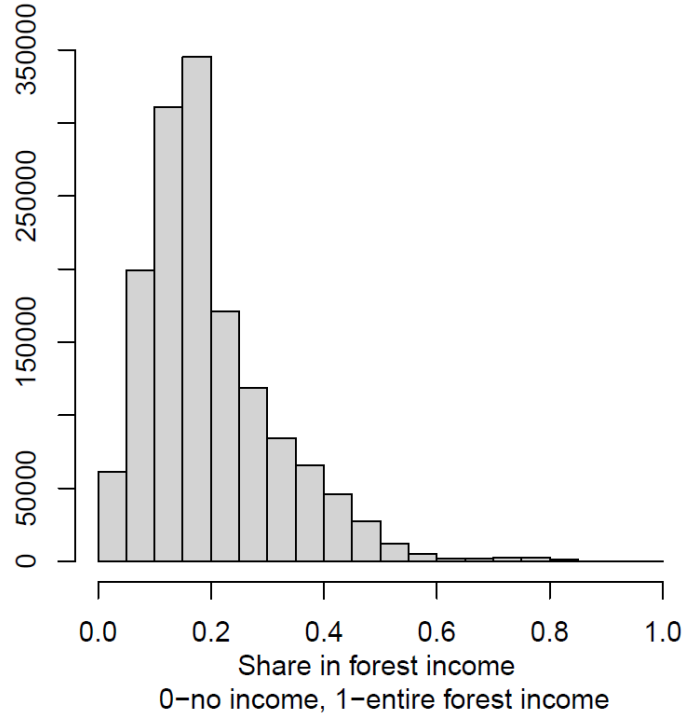
PROVISIONING FES

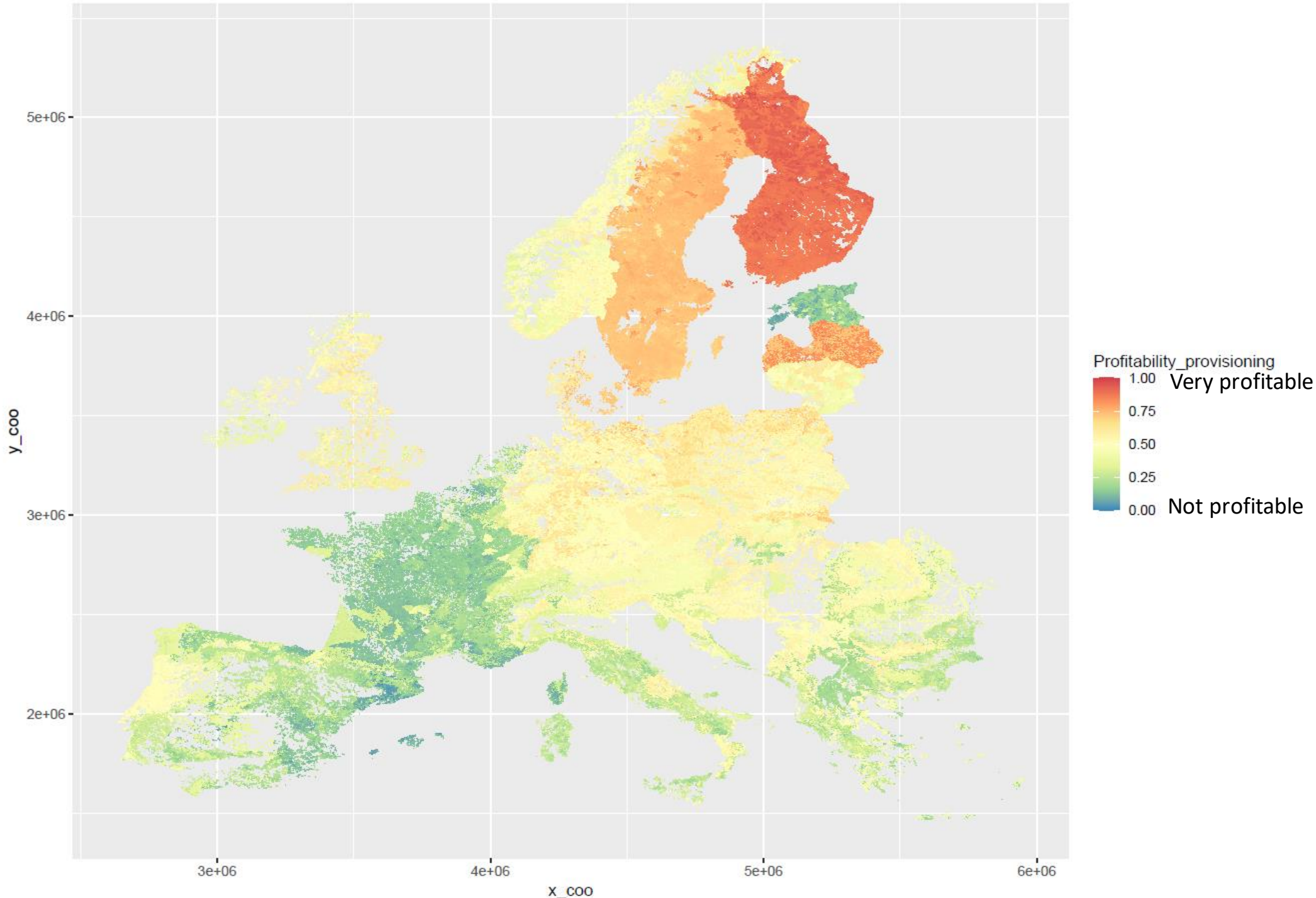


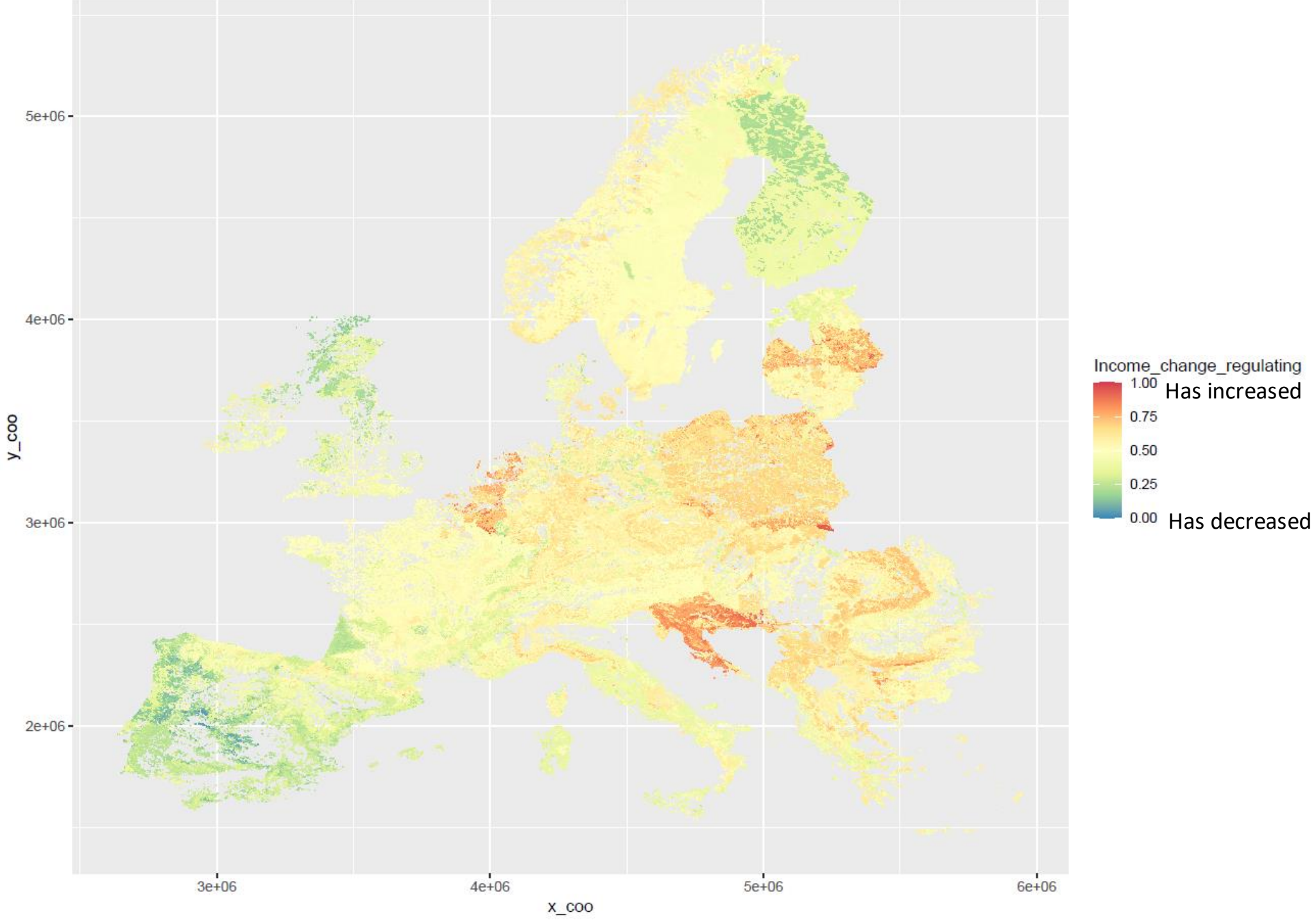
REGULATING FES



CULTURAL FES




5e+06
4e+06
3e+06
2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
x_coo
Profitability_provisioning
1.00
0.75
0.50
0.25
0.00
Very profitable
Not profitable

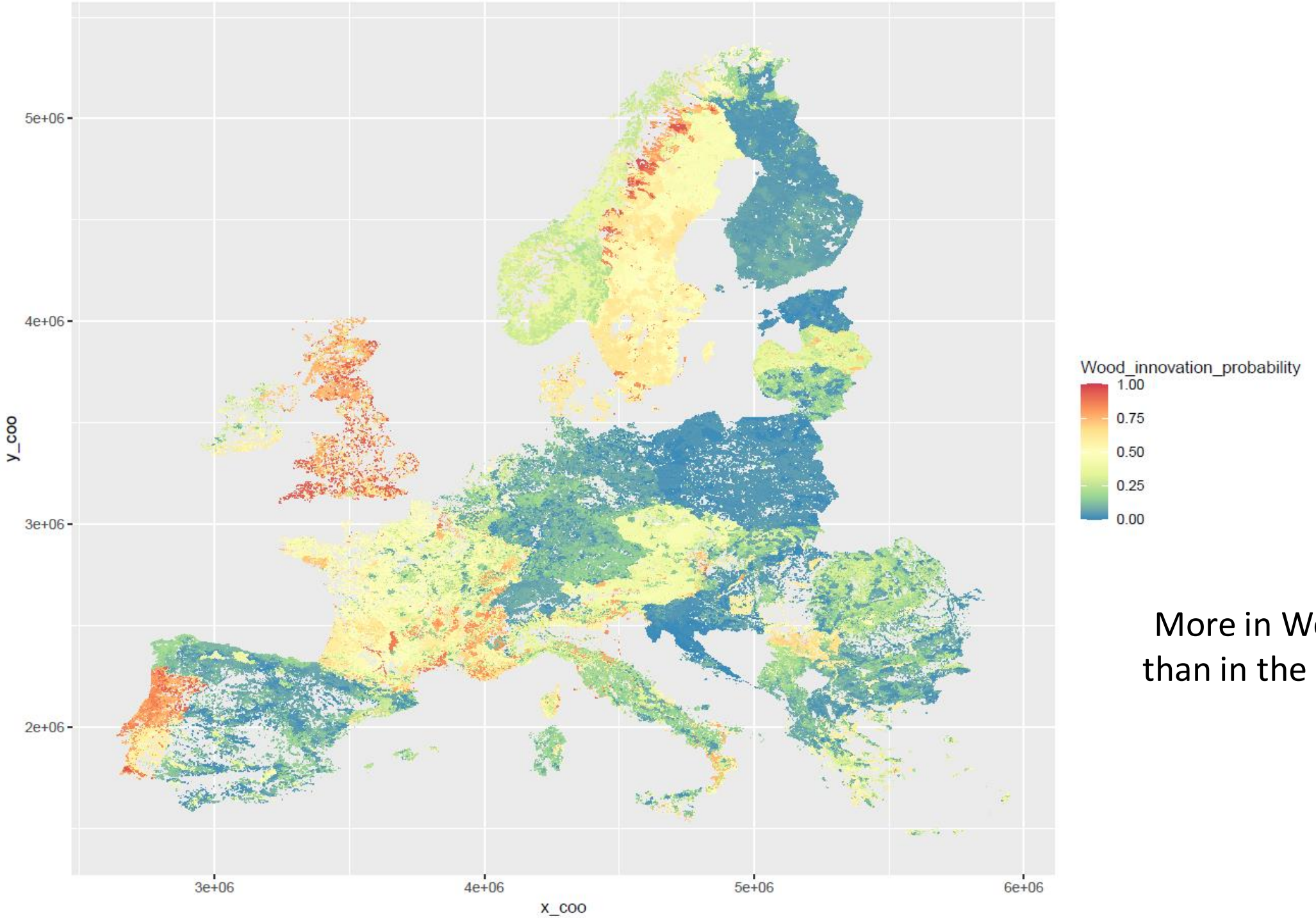

5e+06
4e+06
3e+06
2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
x_coo
Income_change_regulating
1.00
0.75
0.50
0.25
0.00
Has increased
Has decreased

FACTOR ANALYSIS – INCOME AND PROFITABILITY

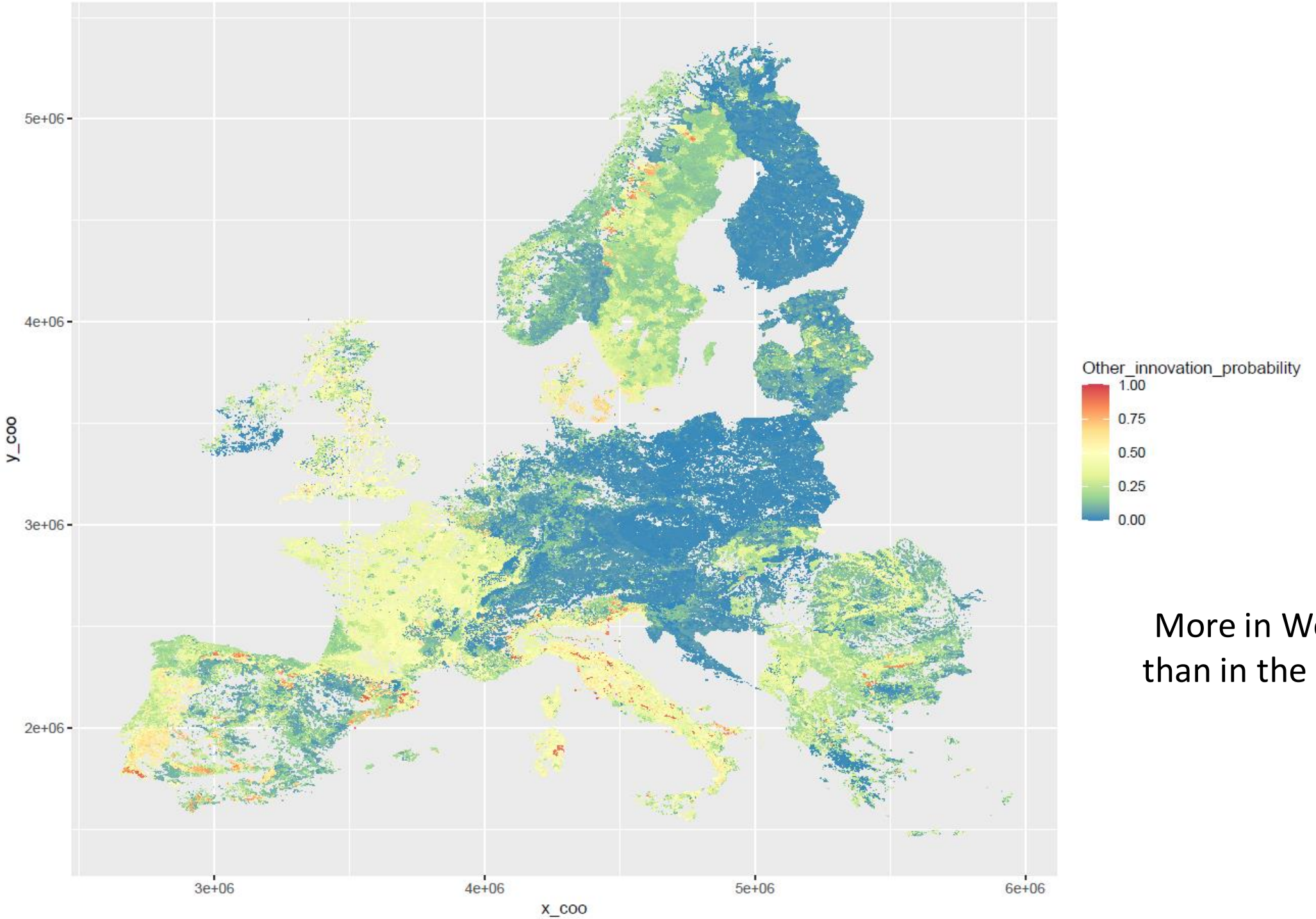
Eigenvalue	4.182995	2.780032	1.336414
	Factor1	**Factor2**	**Factor3**
Income provisioning	-0.12448	0.891022	0.138305
Income regulating	0.924738	-0.03187	0.191245
Income cultural	0.910215	-0.01931	0.358387
Income change provisioning	0.004513	0.939252	-0.0363
Income change regulating	0.29561	-0.05468	0.663574
Income change cultural	0.138444	0.117893	0.980788
Profitability provisioning	0.041323	0.995859	-0.03996
Profitability regulating	0.960822	-0.02288	0.013676
Profitability cultural	0.962064	-0.01934	0.226229

CLUSTERS of forests (income and profitability)

	CLUSTER 1 (863 850 cases) Has sig. higher values for	**CLUSTER 2 (595 091 cases) Has sig. higher values for**
Dependent variables	Profitability of provisioning FES Income change of all FES Income of provisioning FES	Profitability of regulating and cultural FES Income of regulating and cultural FES
Geography	More to the East More to the North	More to the West More to the South
GIS forest data	Carbon and biomass; Growing stock volume; Joint SPA and SAC areas (Natura 2000)	Population density, Closer to a city, Evapotranspiration, Increment, rainfall, Slope, Soil bearing capacity, Terrain ruggedness, Natura 2000 – SPAs (birds) and SACs (habitats)
Tree species	Birch, Larch, Spruce, Scots pine (coniferous in general)	Silver fir, alder, hornbeam, chestnut, eucalyptus, beech, ash, maritime pine, willow, Douglas fir, oak, black locust (broadleaves in general)



More in West than in the East



More in West than in the East

SUMMARY OF RESULTS

- FES supply and demand follow one another on European level
- There are strong regional / national differences in FES supply & demand
- Majority (≈ 80%) of forest income comes from provisioning

  … but still we have the remaining 20% coming from regulating and cultural FES
- Higher probability of innovations in the West than in the East

Main policy implication

(financing of) multifunctional forestry - is it there?

DISCUSSION

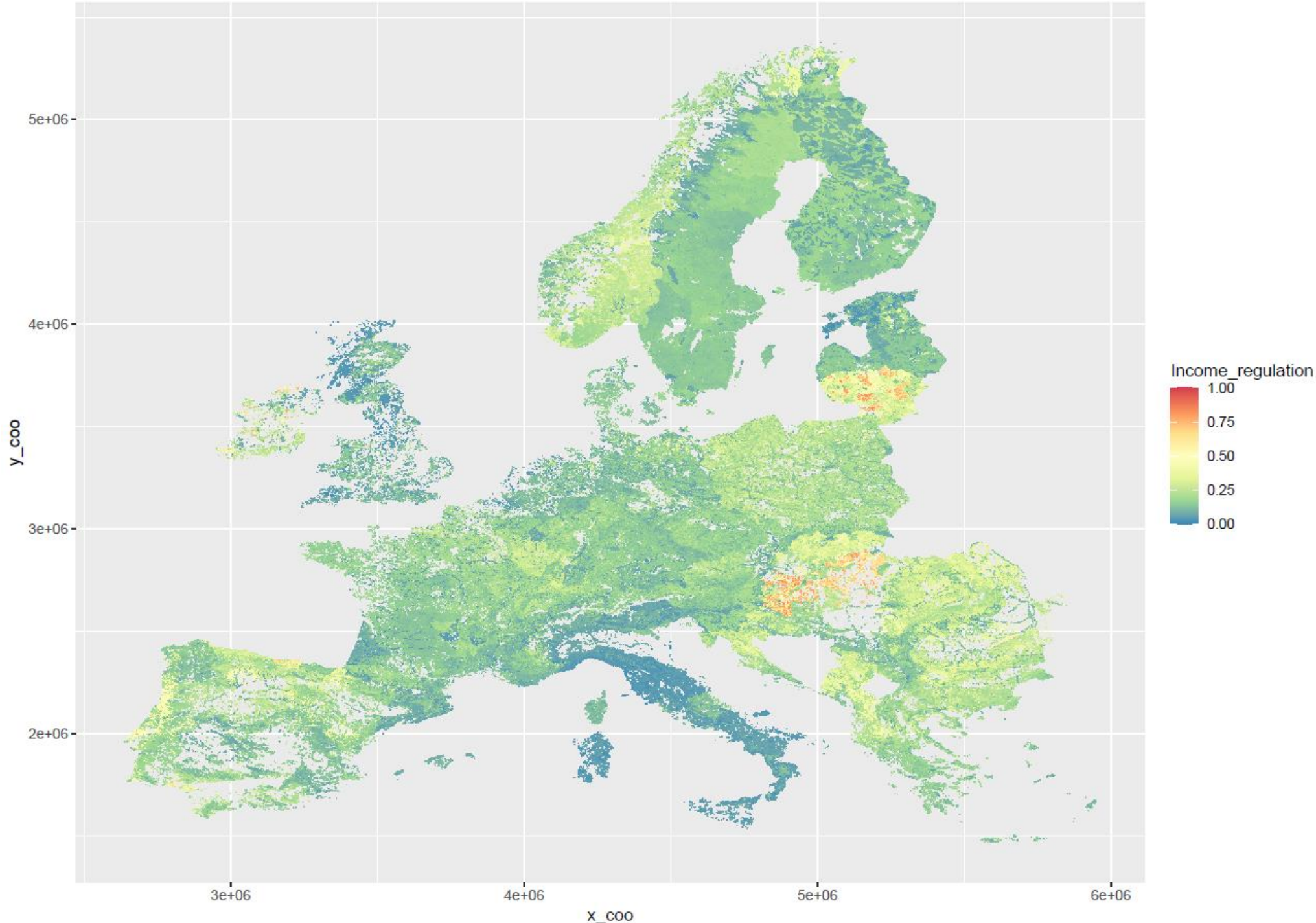
- What did we measure?
  Perceptions of …
    … FES S&D
    … income and profitability
    … occurrence of innovations

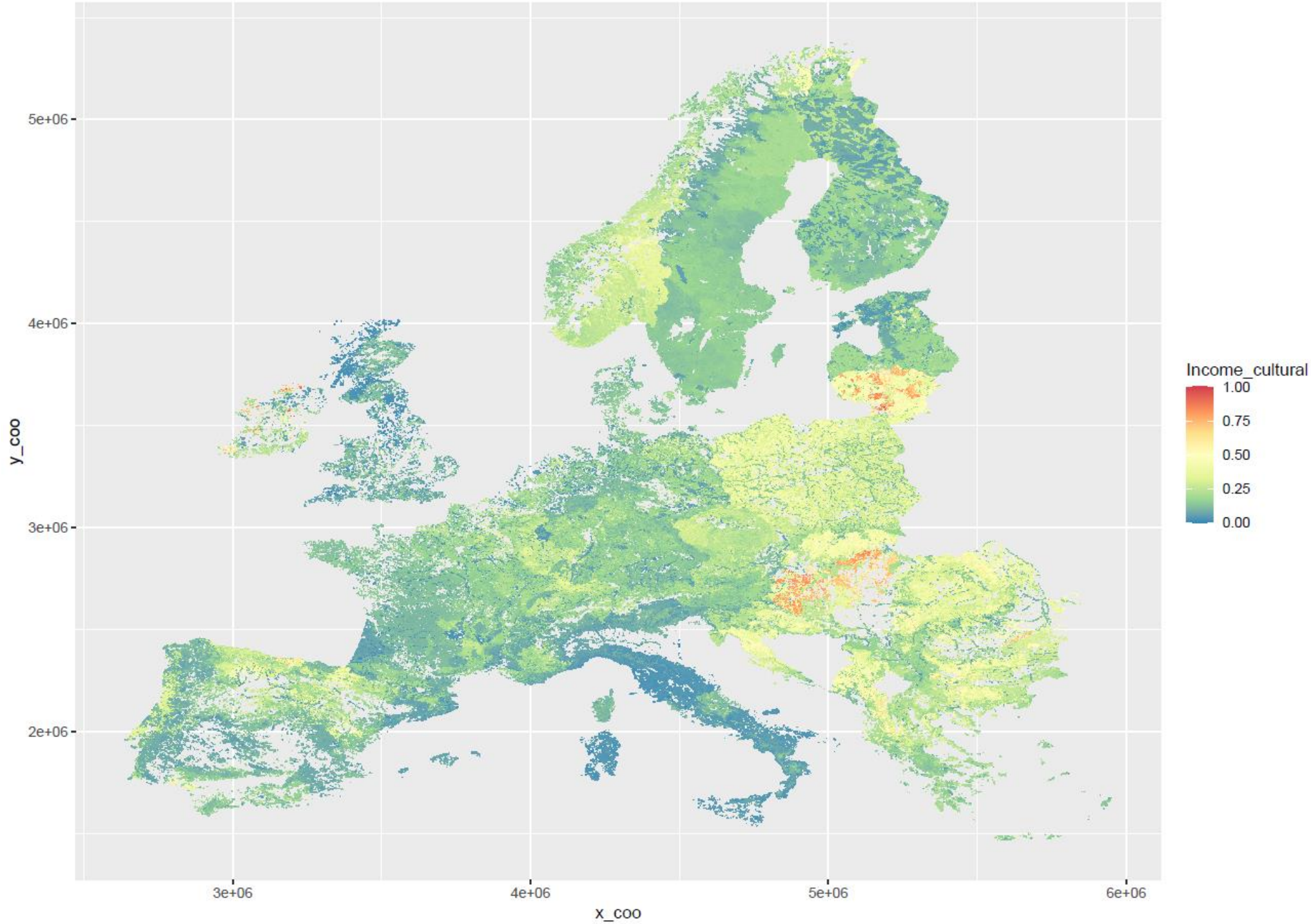
Reliability

- Are there some other explanations of these FES variables?
  Short answer: **YES**
  Little longer answer: Legislation, annual allowable cut, differences in perception, institutional framework, etc..

- What to do next?
  - Compare these to other FES mapping
  - Disseminate the main results (e.g. Financing – provisioning vs. regulating & cultural
  - Re-assess / further analyze the data (still in progress)

THANK YOU


5e+06
4e+06
3e+06
2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
x_coo
Income_regulation
1.00
0.75
0.50
0.25
0.00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2e+06
y_coo
3e+06
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5e+06
6e+06
x_coo
Income_cultural
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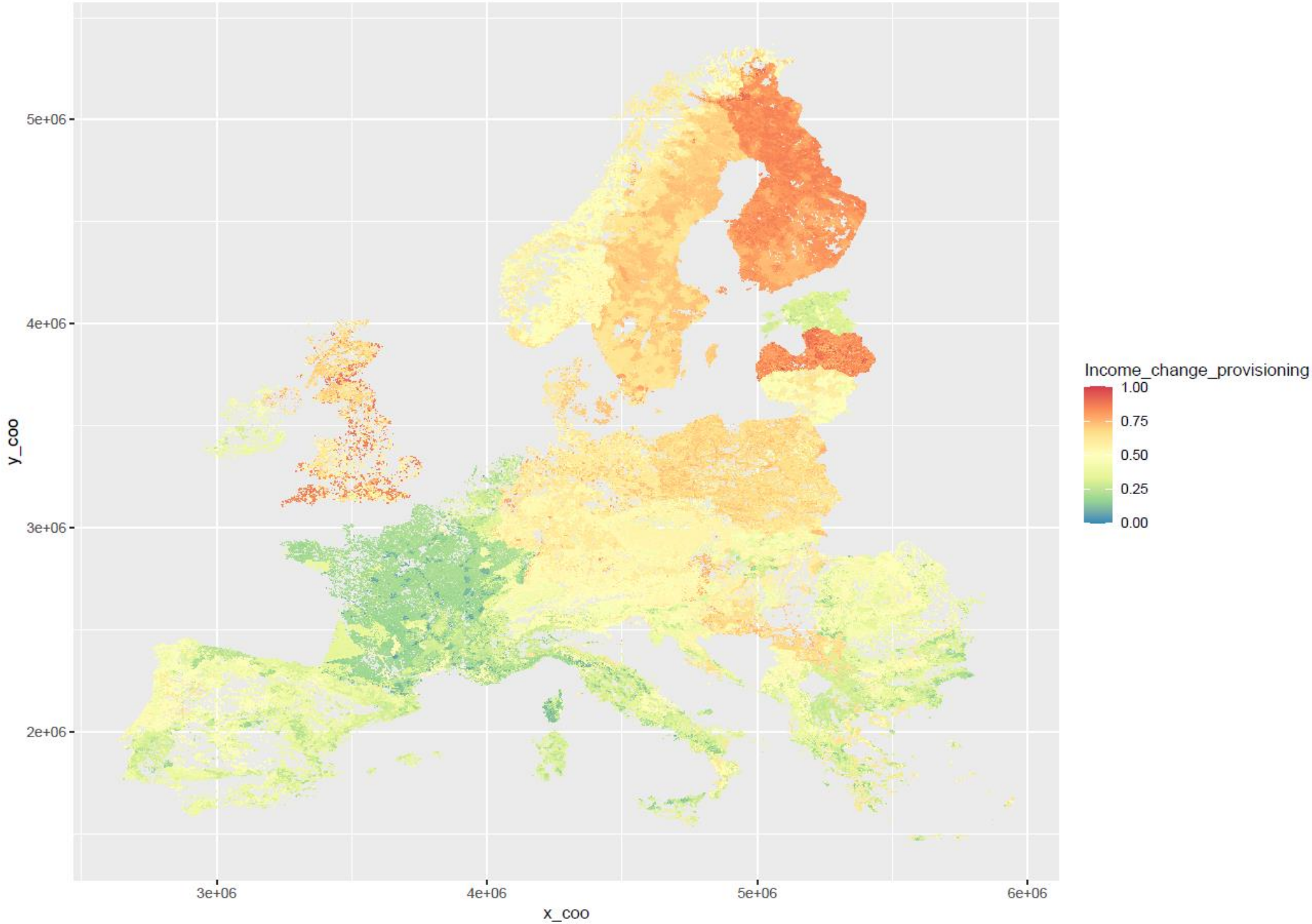
0.75
0.50
0.25
0.00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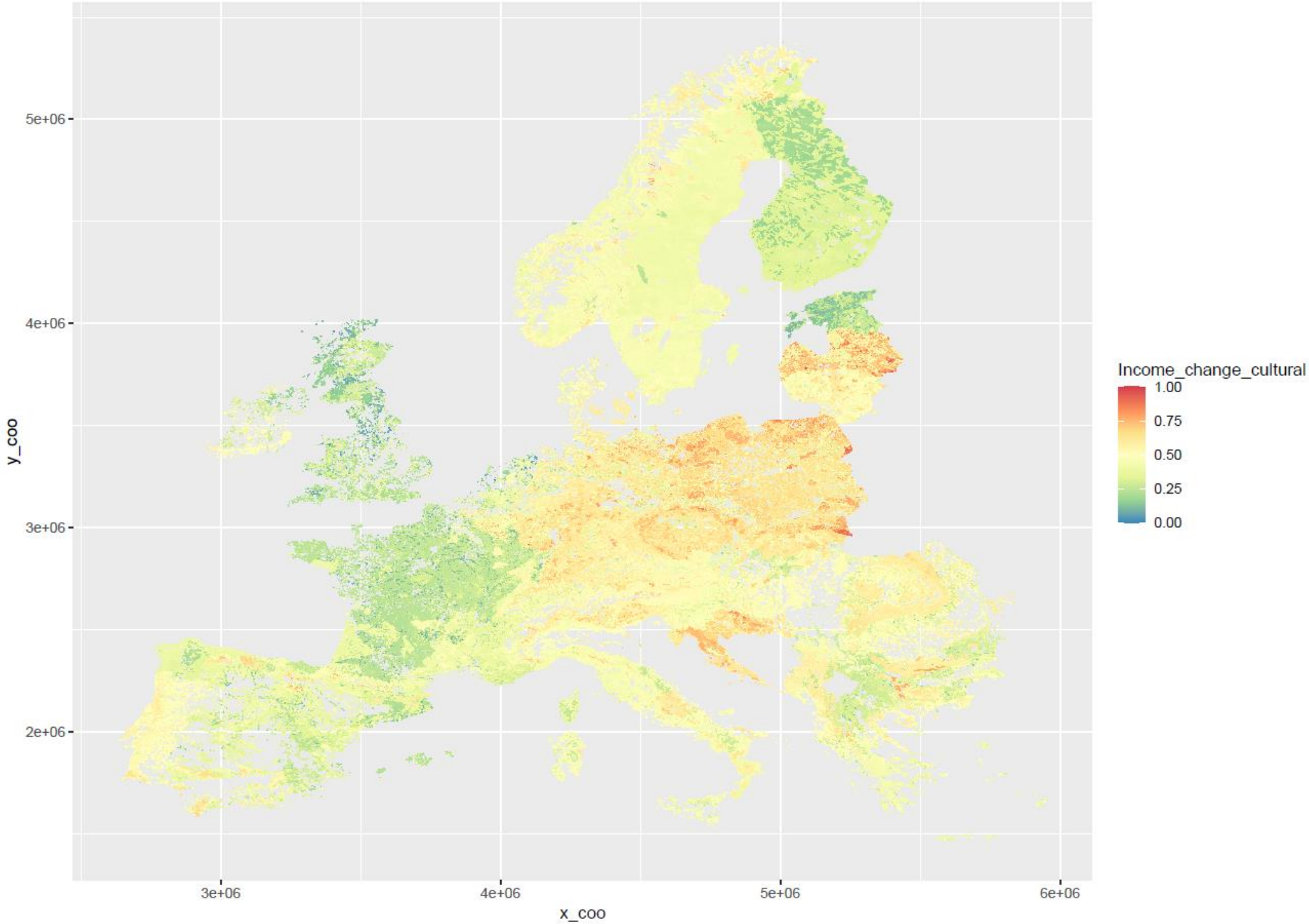
4e+06
3e+06
2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
x_coo
Income_change_provisioning
1.00
0.75
0.50
0.25
0.00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2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
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Income_change_cultural
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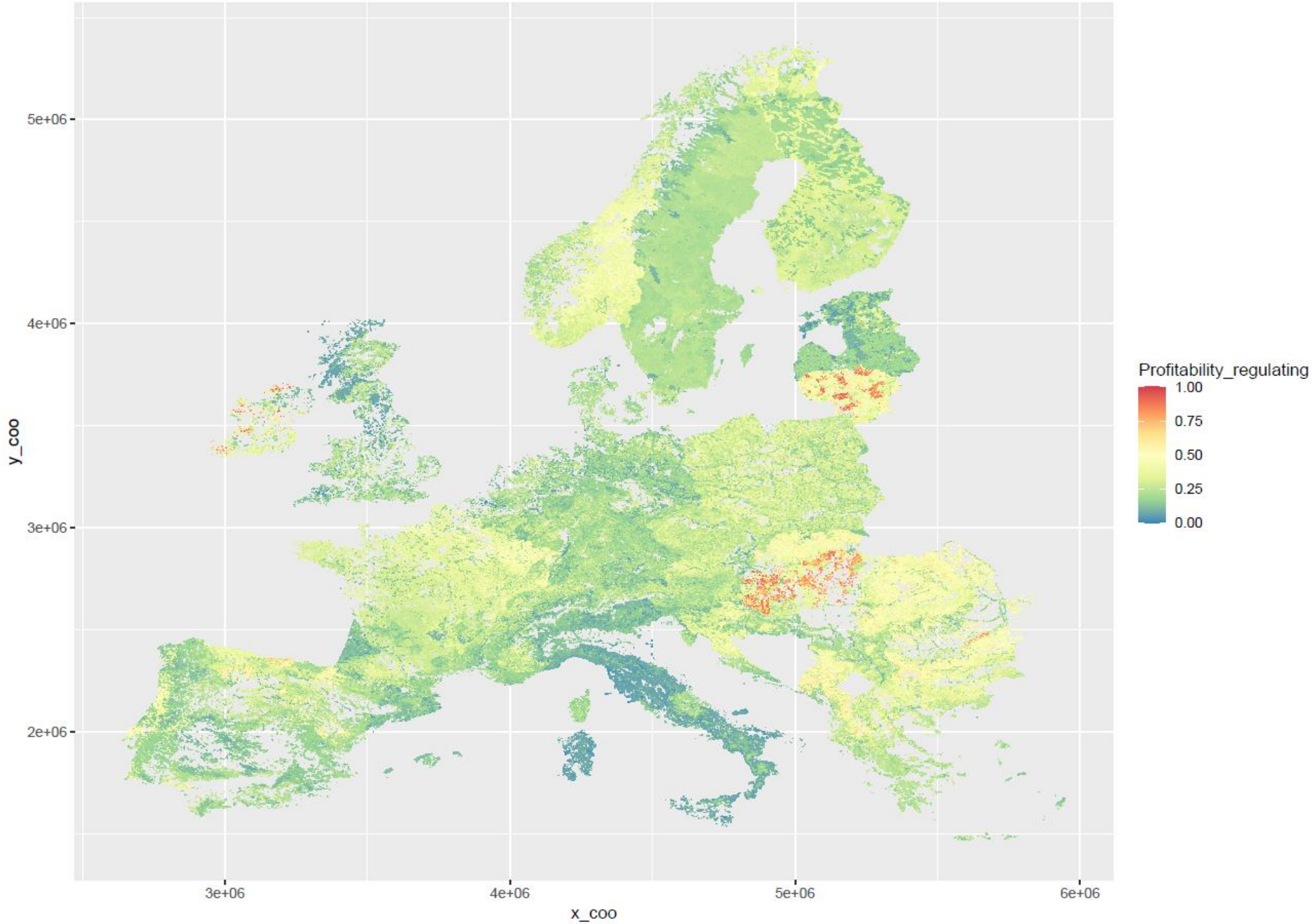
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4e+06
3e+06
2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
x_coo
Profitability_regulating
1.00
0.75
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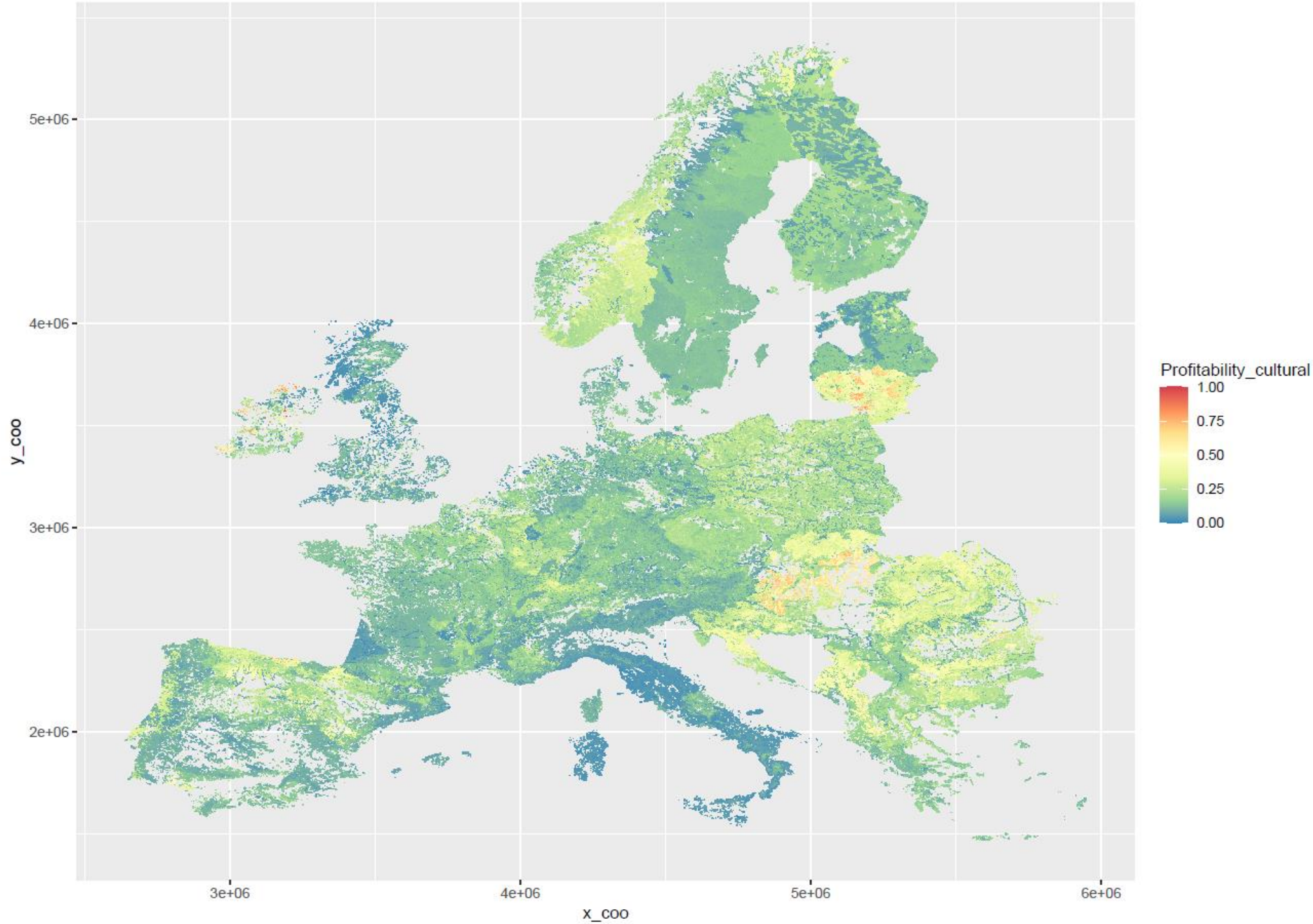
0.00


5e+06
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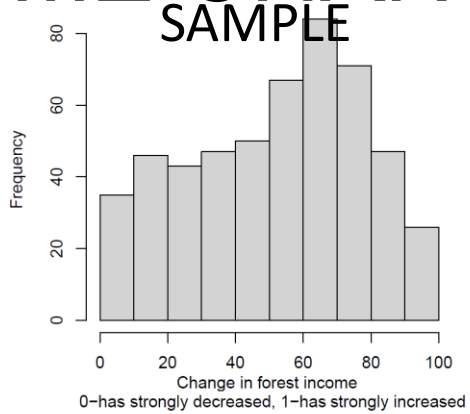
3e+06
2e+06
y_coo
3e+06
4e+06
5e+06
6e+06
x_coo
Profitability_cultural
1.00
0.75
0.50
0.25
0.00

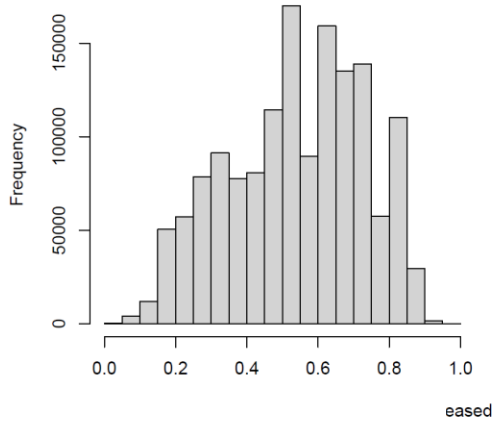
INCOME CHANGE FROM FES

SAMPLE

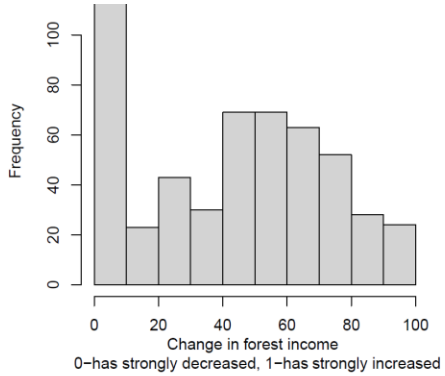
ALL FORESTS

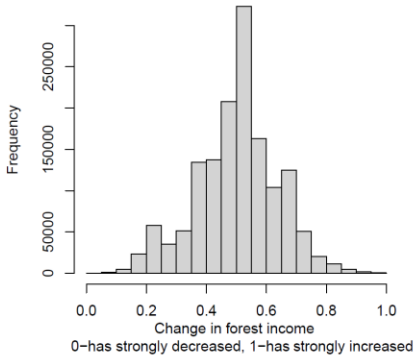
PROVISIONING



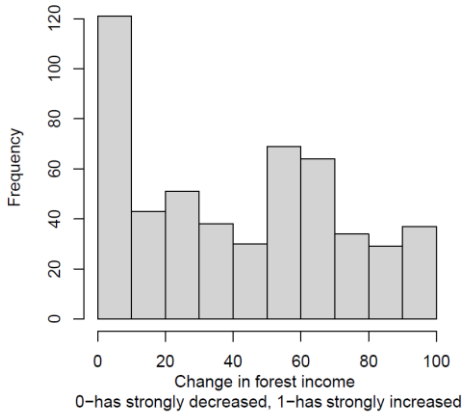


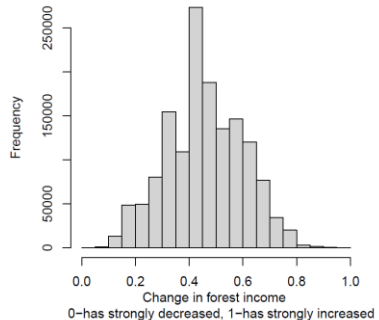
REGULATING



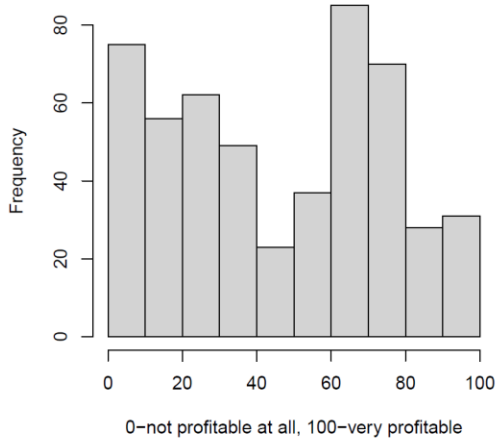
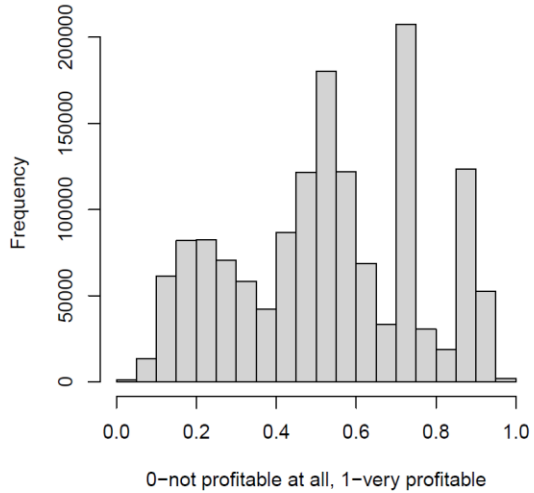
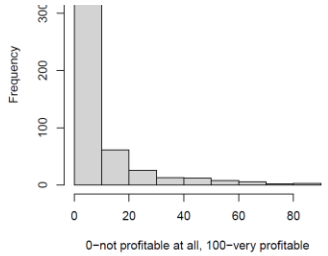
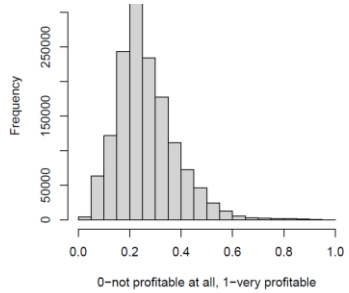
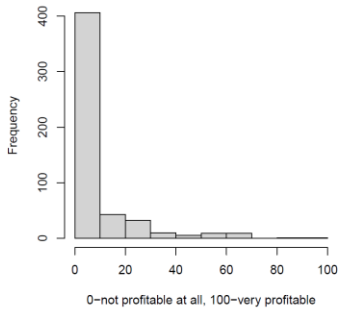
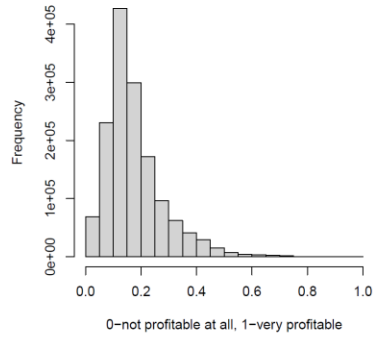


CULTURAL





PROFITABILITY FROM FES

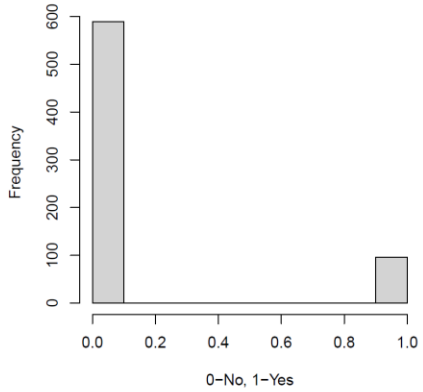
	SAMPLE	ALL FORESTS
PROVISIONING		
REGULATING		
CULTURAL		

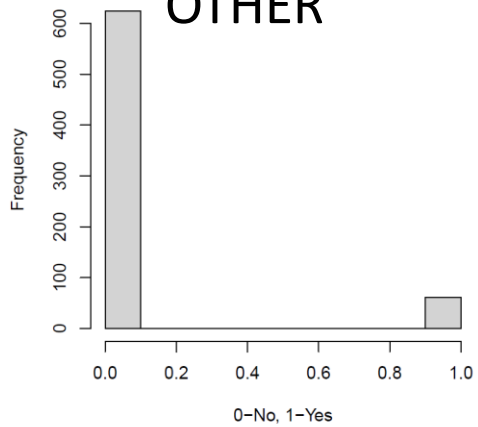
INNOVATIONS PROBABILITY

WOOD

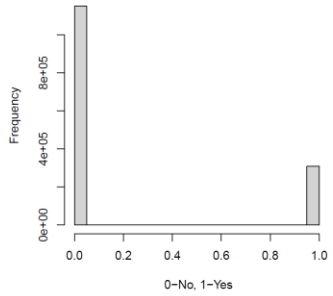
OTHER

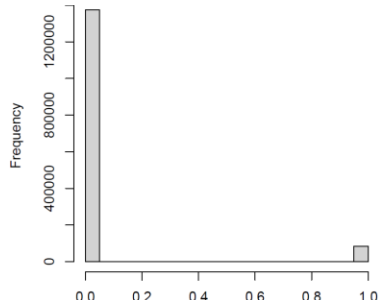
SAMPLE BINARY



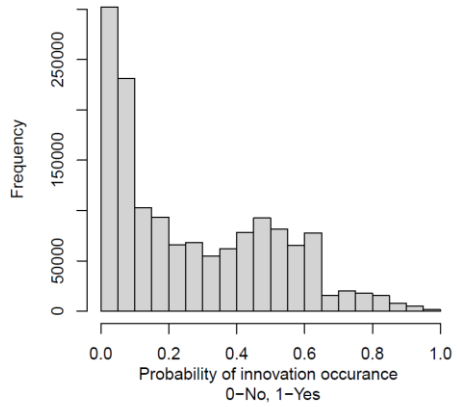


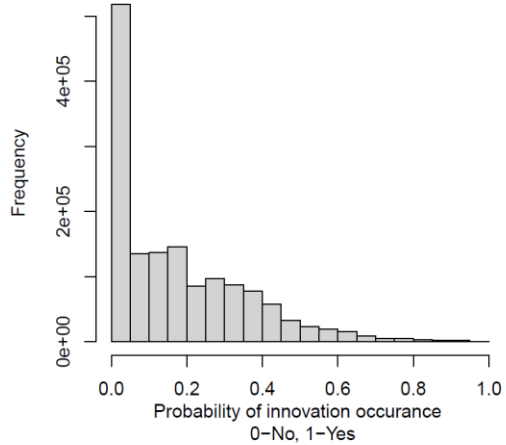
ALL FORESTS BINARY





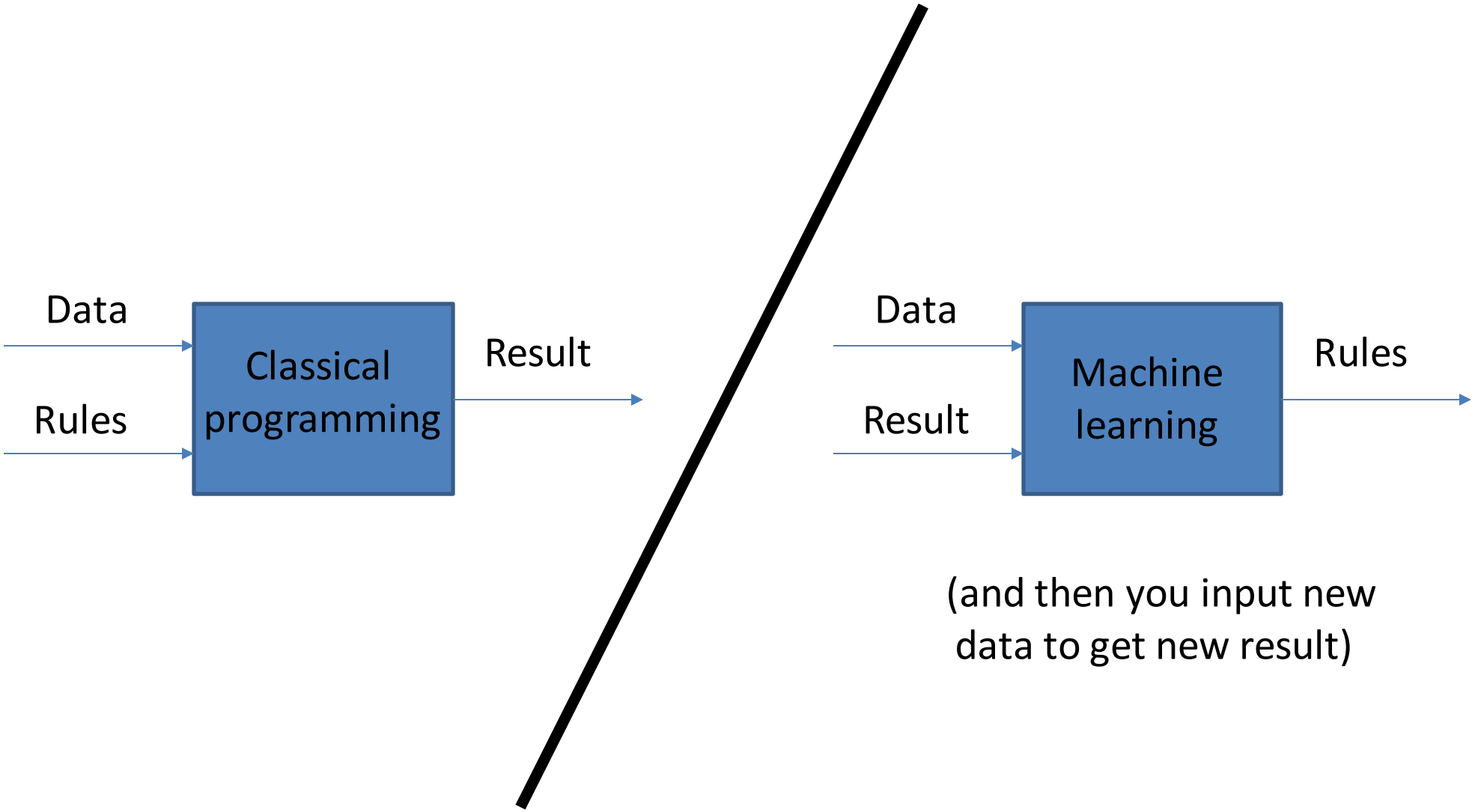
ALL FORESTS PROBABILITY



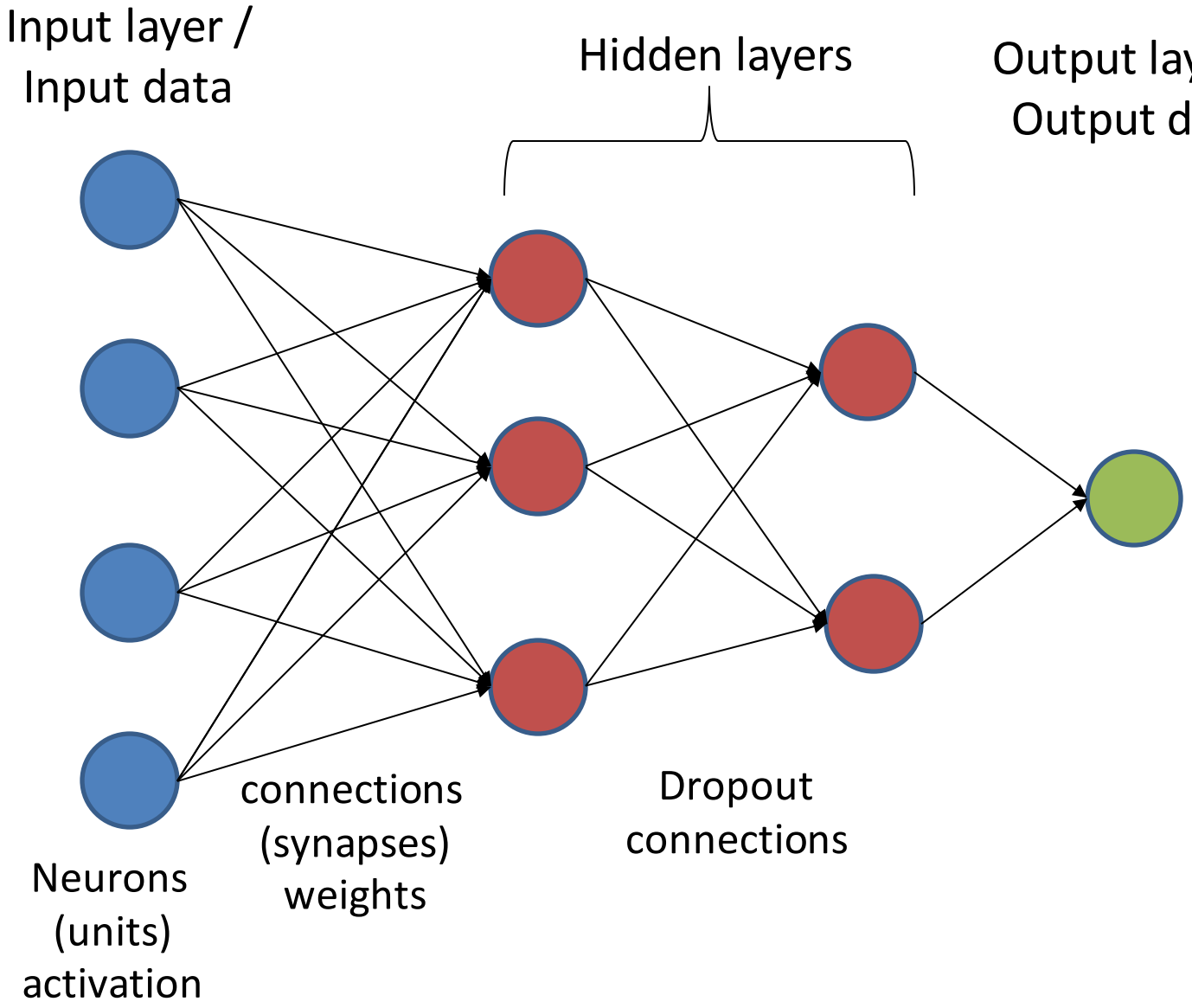


Name	Description	Measurement unit	Description	Reference
abelow_biom	Above- and below-ground biomass	tons km^{-2}	Pan-European map of living forest above and below-ground biomass produced by JRC (resolution: 1 km).	Barredo Cano et al. (2012)
abelow_carbon	Above- and below-ground carbon	tons km^{-2}	Pan-European map of living forest above and below-ground carbon produced by JRC (resolution: 1 km).	Barredo Cano et al. (2012)
above_biomass	Above-ground biomass	tons km^{-2}	Pan-European map of living forest above-ground biomass produced by JRC (resolution: 1 km).	Barredo Cano et al. (2012)
above_carbon	Above-ground carbon	tons km^{-2}	Pan-European map of living forest above-ground carbon produced by JRC (resolution: 1 km).	Barredo Cano et al. (2012)
accessibility	Travel time to closest city with population greater than 50,000 in 2000	Minutes	Travel time map from cities greater than 50,000 people produced by JRC and World Bank (resolution: 1 km)	Nelson (2008)
density	Population density (GEOSTAT)	People km^{-2}	Vector map of population density (1km x 1km polygons)	Eurostat (2011)
et	Reference evapotranspiration	mm yr^{-1}	Map of global potential evapotranspiration produced by CGIAR (resolution: 1 km)	Zomer et al. (2008)
gsv	Growing stock volume	m^3 ha^{-1}	Volume of all living trees more than 10 cm in diameter at breast height measured over bark from ground or stump height to a top stem diameter of 0 cm for the year 2010 (resolution: 1 km)	Santoro et al. (2018)
increment	Forest biomass increment	ton ha^{-1} yr^{-1}	Pan-European map of forest biomass increment (resolution: 1 km)	Busetto et al. (2014)
rainfall	Average annual rainfall (1970-2000)	mm yr^{-1}	Summation of average monthly rainfall for the period 1970-2000 (resolution: 1 km)	Fick et al. (2017)
slope	Average slope	Degrees	Slope computed from the EU-DEM from Copernicus resampled at a 1-km resolution	
bearing_cap	Soil bearing capacity JRC data by Hans	0, if the soil is not a constraint, or 1, if the pixel has zero soil bearing capacity (soil type Histosol, Fluvisol, Gleysol and Andosol in layer FAO85lv1	JRC data	
access2015	travel time to cities 2015		New map of global accessibility (resolution: 1 km)	Weiss et al. (2018)
ruggedness	terrain ruggedness	The terrain ruggedness is expressed in meters (for converting the value in meter into a level of ruggedness, one can refer to the article you sent me)		Riley et al. (1999)
ownership	Forest ownership	Share of private ownership	Ownership map from EFI	Pulla et al. (2013)
asites_forest	type A sites Natura 2000 (i.e. SPAs),		0/1. 3 is NA	Link
bsites_forest	B sites Natura 2000 (i.e. SCIs and SACs)		0/1. 3 is NA	Link
csites_forest	Joint A and B site		0/1	Link

MACHINE LEARNING



MACHINE LEARNING (sequential model example)



MACHINE LEARNING (script overview)

Model define (previous slide)

Model compile – optimizer and loss functions

Defines the next estimation based on loss

Defines how good/bad estimation is

X – input data

Y – output data

Model fit (X, Y, epochs = 500)

Use this

To estimate this

And repeat it 500 times

Model predict (on a new input data)

MACHINE LEARNING (training)

SURVEY QUESTIONS

2. Profitability and income

- Share of FES income in entire forest income (labeled **income**)
- Change of relative share FES income in entire forest income in the last 20 years (labeled **income change**)
- Profitability of FES income (labeled profitability)

Separately for provisioning, regulating and cultural FES (0-1 scale)

3. Presence of FES-related innovations (0/1)

- Wood-focused innovations (technology for biomass production, e.g. usage of harvester instead of chainsaws or using satellite imagery for identifying logging sites; New way to generate value e.g. organizing auctions for high-quality timber; Change of forest management to improve / sustain biomass production e.g. new thinning measures for increased wood increment or for increased resilience)
- Innovations focused on other FES (new ecosystem service such as a pollination strip or burial forest; New technology for other ecosystem services e.g. a new technology for extracting resin; Change of forest management to provide other ecosystem services e.g. new thinning measures for growth of mushrooms or support nature tourism; New communication or marketing strategy implemented e.g. a website or a hired branding professional; New users of ecosystem service e.g. children or urban citizens; New trans-sectoral contract created e.g. a new agreement with conservation groups or eco-tourism enterprises; New transboundary cooperation created e.g. a sustainable tourism project across country borders)

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Coordinator EFI

BCSD Business Council for Sustainable Development
RESPONSIBLE BALANCE

CIFOR

Generalitat de Catalunya
Departament d'Agricultura, Ramaderia, Pesca i Alimentació
Centre de la Propietat Forestal

CEPF

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