A FOSS4G model to estimate forest extraction methods and biomass availability for energy production

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Introduction

Energy production is one of the most important future challenges for human societies because of the decreasing availability of traditional energy resources.

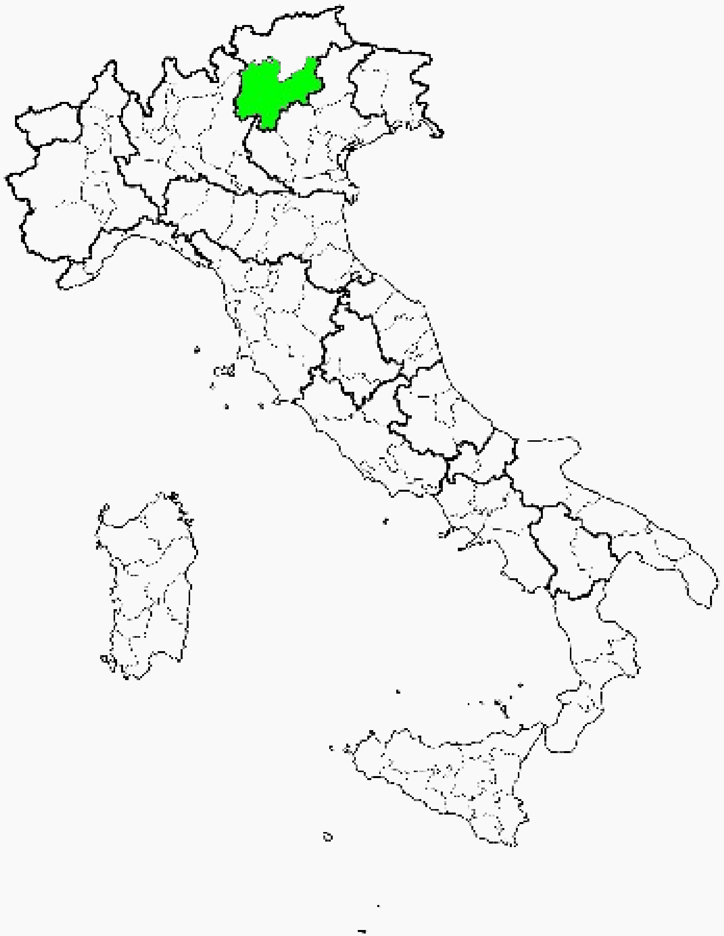
In a forest rich region, like the Italian Alps, one of the main renewable energy source is the wood biomass available in its forests and EU aims to triple bio-energy production compared to 1999 levels within 2010.

Therefore, a model based on the FOSS4G framework to estimate biomass availability for energy production in an alpine area has been developed.

Several models have been developed to estimate availability of biomass forestry residues for energy use at different scales, most of them focus on logistic problems and optimization, regardless of the fact that biomass availability depends on the extraction techniques.

An innovative model has been created, evaluating the actual biomass availability in a GIS environment taking into account the possible biomass harvesting techniques and their effective yield.

Study Area – Trentino, Italy



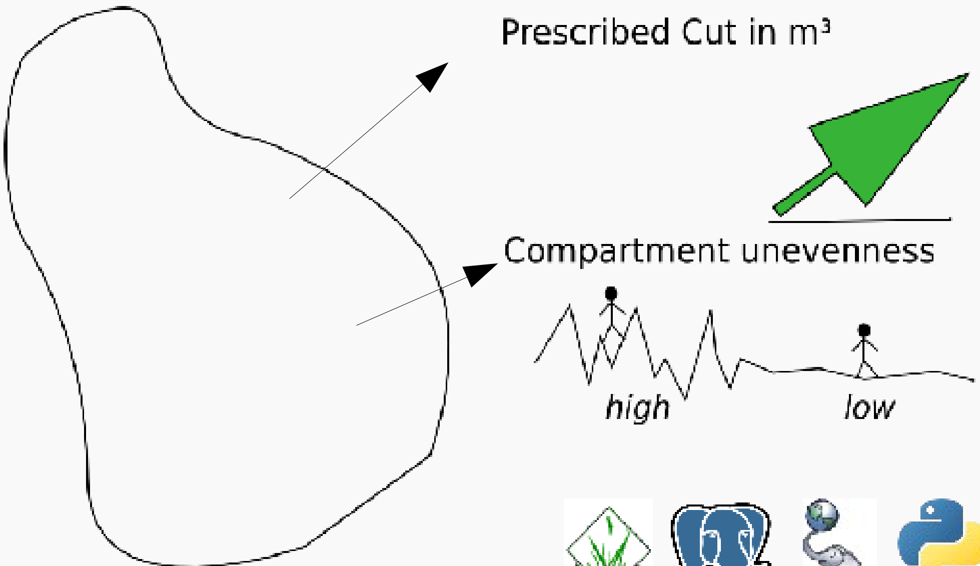
- 58% covered by forest;
- mean annual forest production is 500'000 m³ by Forestry Plan management, 330'000 m³ commercial of coniferous wood;
- sustainable forest management techniques;
- in the last 50 years, forest cover expanded, taking up areas which were used as pastures;
- mechanization levels are still too low to gain an economic advantage from the recover, chipping and collecting of biomass.

Input Data

1. Digital elevation model (**DEM - 10m**);

2. Main roads and forestry tracks;

3. High forest data (**P**iani **E**conomico **Fo**restali – Economic Forest Plan, **PEFO**)
   - Compartment code,
   - Forestry department,
   - Compartment unevenness,
   - Prescribed cut,
   - Prescribed cut per ha,
   - Geometry



Extraction Techniques

Ground Skidding

Harvester

Forwarder

Overhead skidding

Cable Crane

Best operating conditions

		Harvester Forwarder	Cable crane or Tower yarder
up hill ↑	Slope	20%	20-120%
	Max distance	800 [m]	1000 [m]
	Unevenness	Low	Any
down hill ↓	Slope	30%	20-120%
	Max distance	800 [m]	1000 [m]

Software

```
> g.region -p
projection: 99
(Transverse Mercator)
zone:        0
datum:       rome40
ellipsoid:
international
North:       5159000
south:       5056840
west:        1609440
east:        1731640
nsres:       10
ewres:       10
rows:        10216
cols:        12220
cells:       124839520
```

The first implementation wanted to preserve simplicity in the installation and usage for final user, the first attempt was implemented entirely in GRASS.

Using r.cost, it is possible to calculate distance and drop, but it is not possible to differentiate between downhill or uphill.

For this reason a bash script was implemented but it was too slow for large regions.

Moreover, the management of a large forest database is more effective in PostgresSQL-PostGIS than in GRASS.

Software

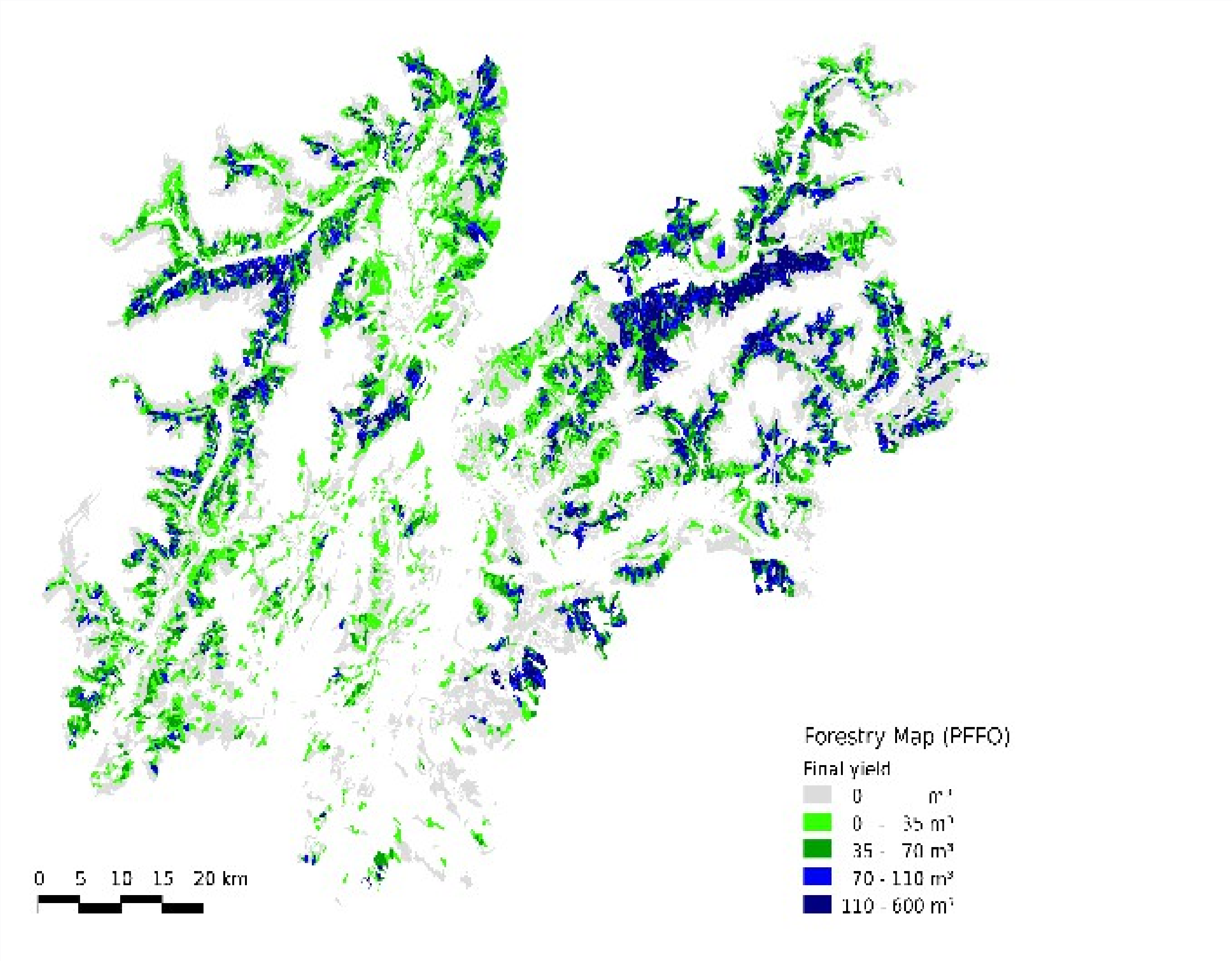
- GRASS 6.4
- PostgreSQL 8.4
- Postgis 1.5
- Python 2.6 (numpy, psycopg2)

The model is completely implemented as a Python GRASS model.

Model

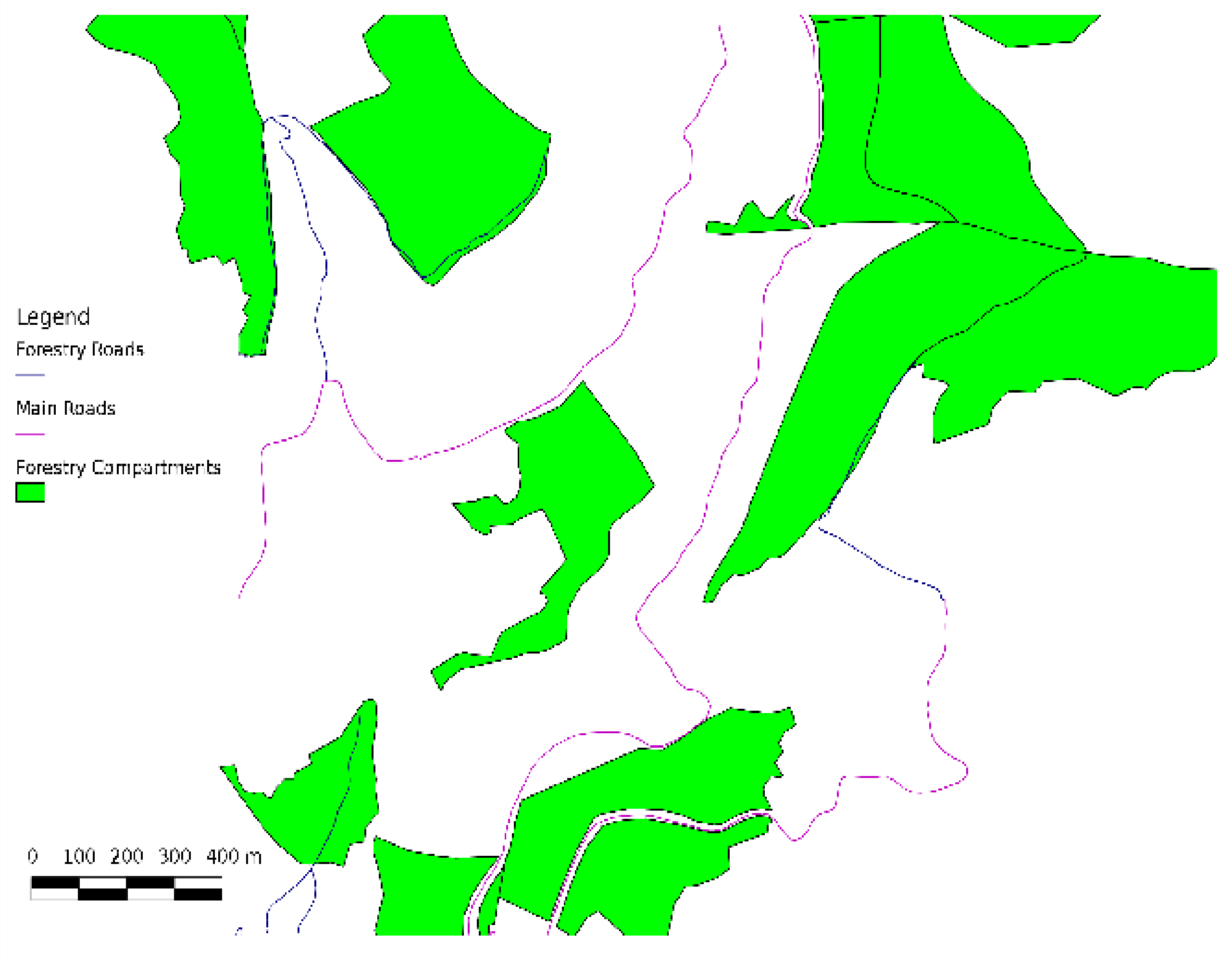
Module	INPUT		DISTANCE	EXCLUDE	ESTIMATE	CONVERSION
Harvester Forwarder	PEFO DEM Roads	Cluster: slope < 30% final yield > 0 Unevenness = 1 Road points	Dist&Drop	dist < 800 m ↑ slope < 20% ↓ slope < 30% [ha/comp.]	[m^3/comp.]	[ton]
Cable crane or Tower yarder	PEFO DEM Roads		Distance	dist. < 1000 m slope 20-120% final yield > 0 [ha/comp.]		

Harvester and Forwarder



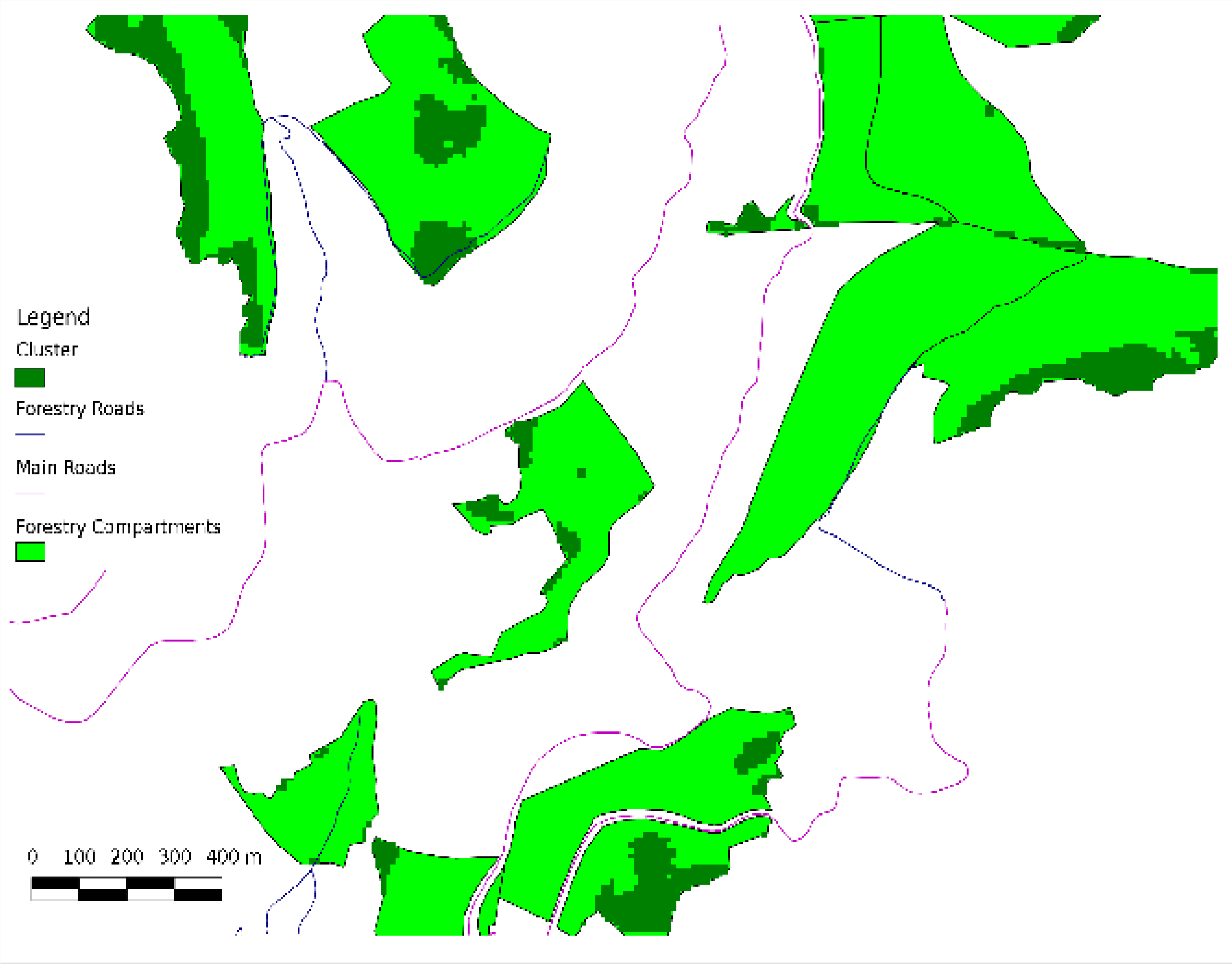
Identify all extractable compartments with prescribed cutting > 0

Harvester and Forwarder



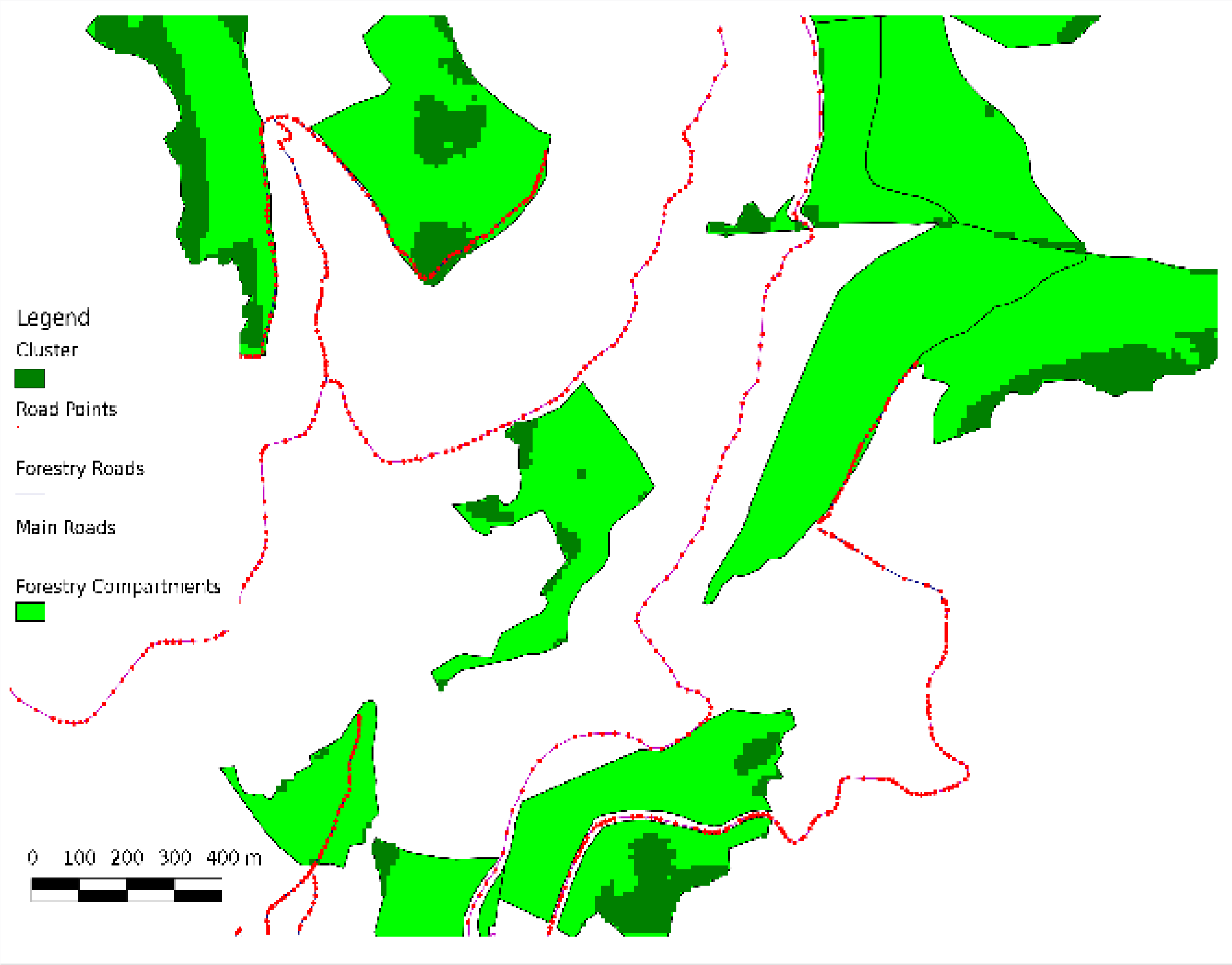
Identify all compartments with low unevenness

Harvester and Forwarder



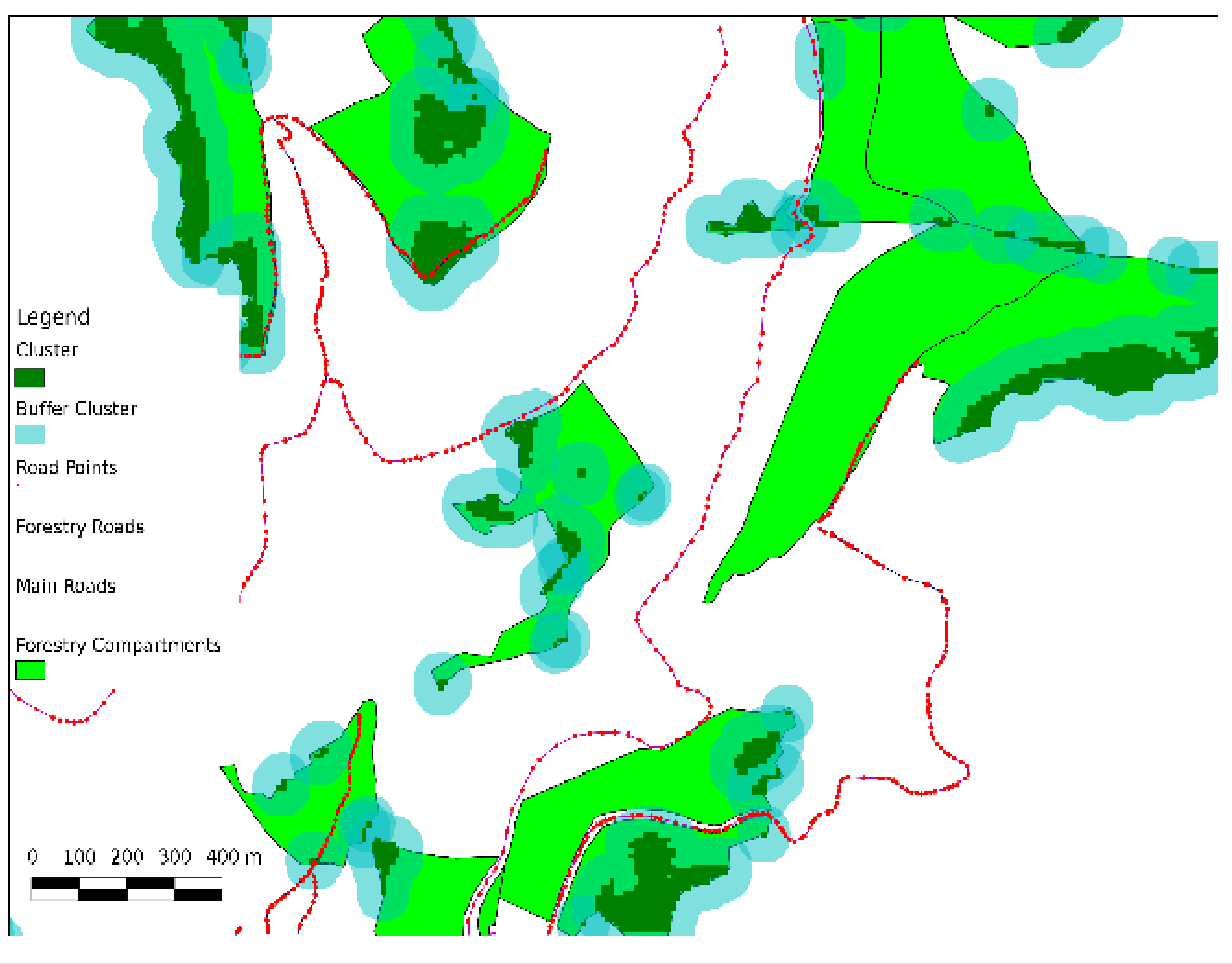
Identify pixels with slope < 30%

Harvester and Forwarder



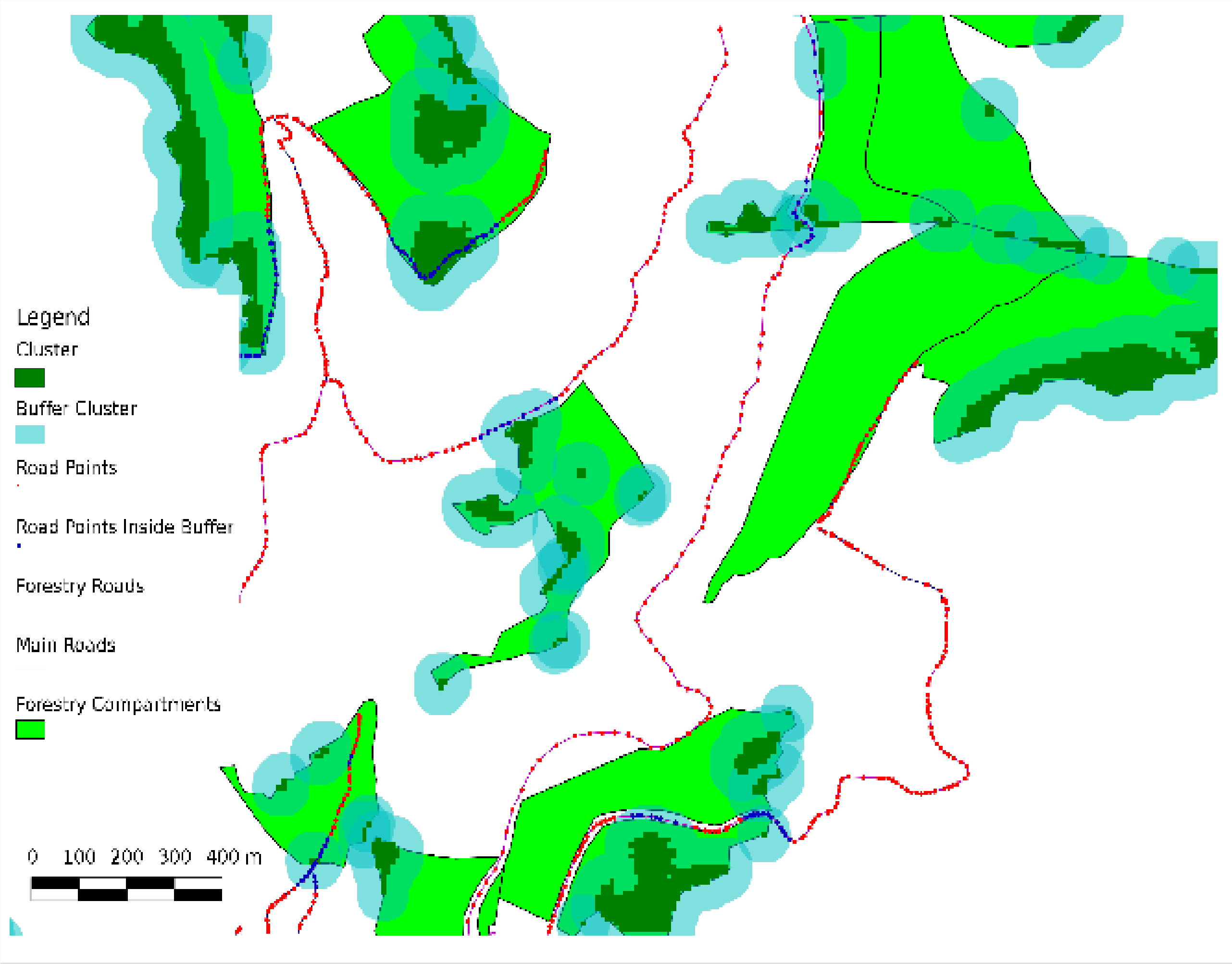
Transform roads geometry into vertex point.

Harvester and Forwarder



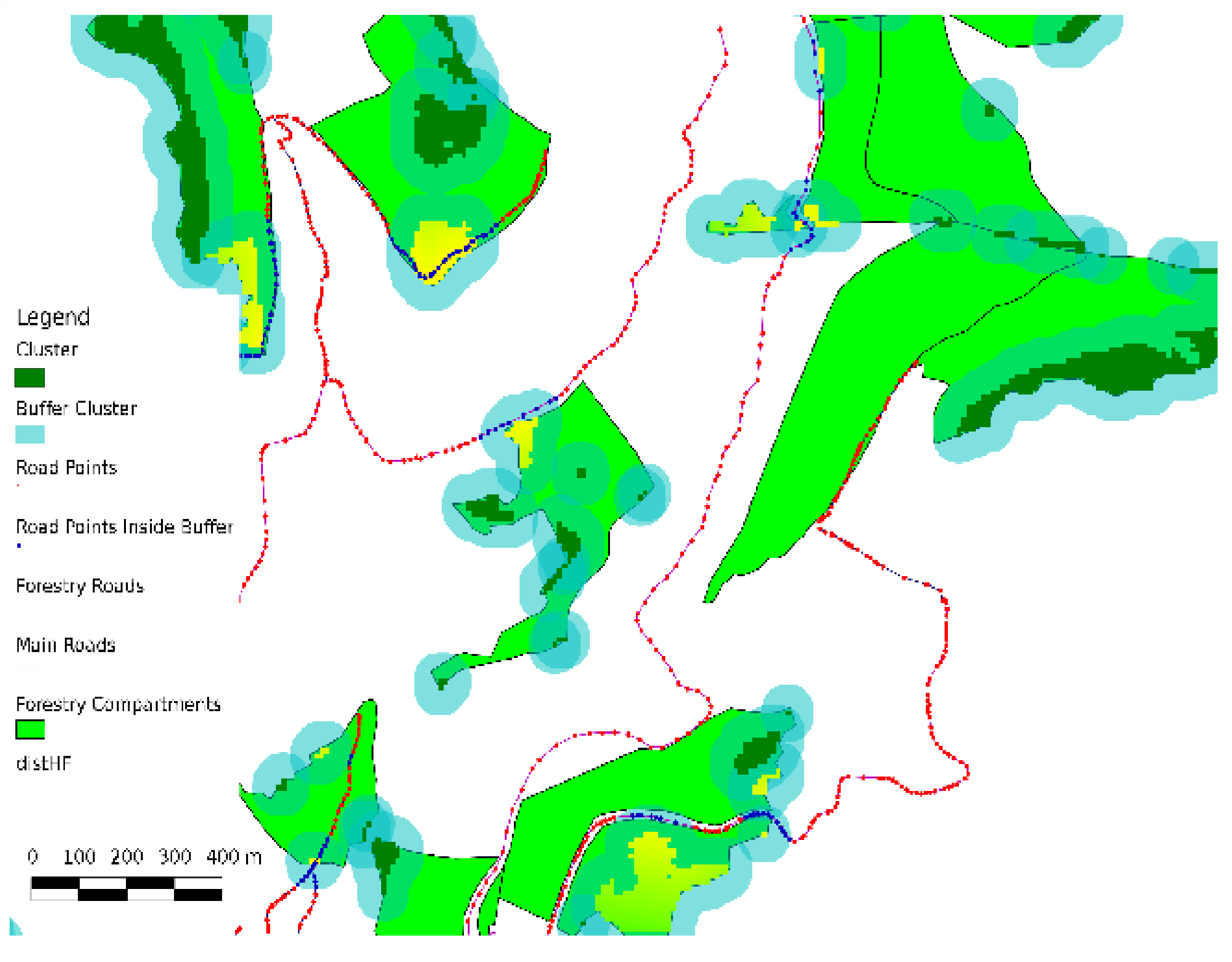
Calculate buffer around the cluster.

Harvester and Forwarder



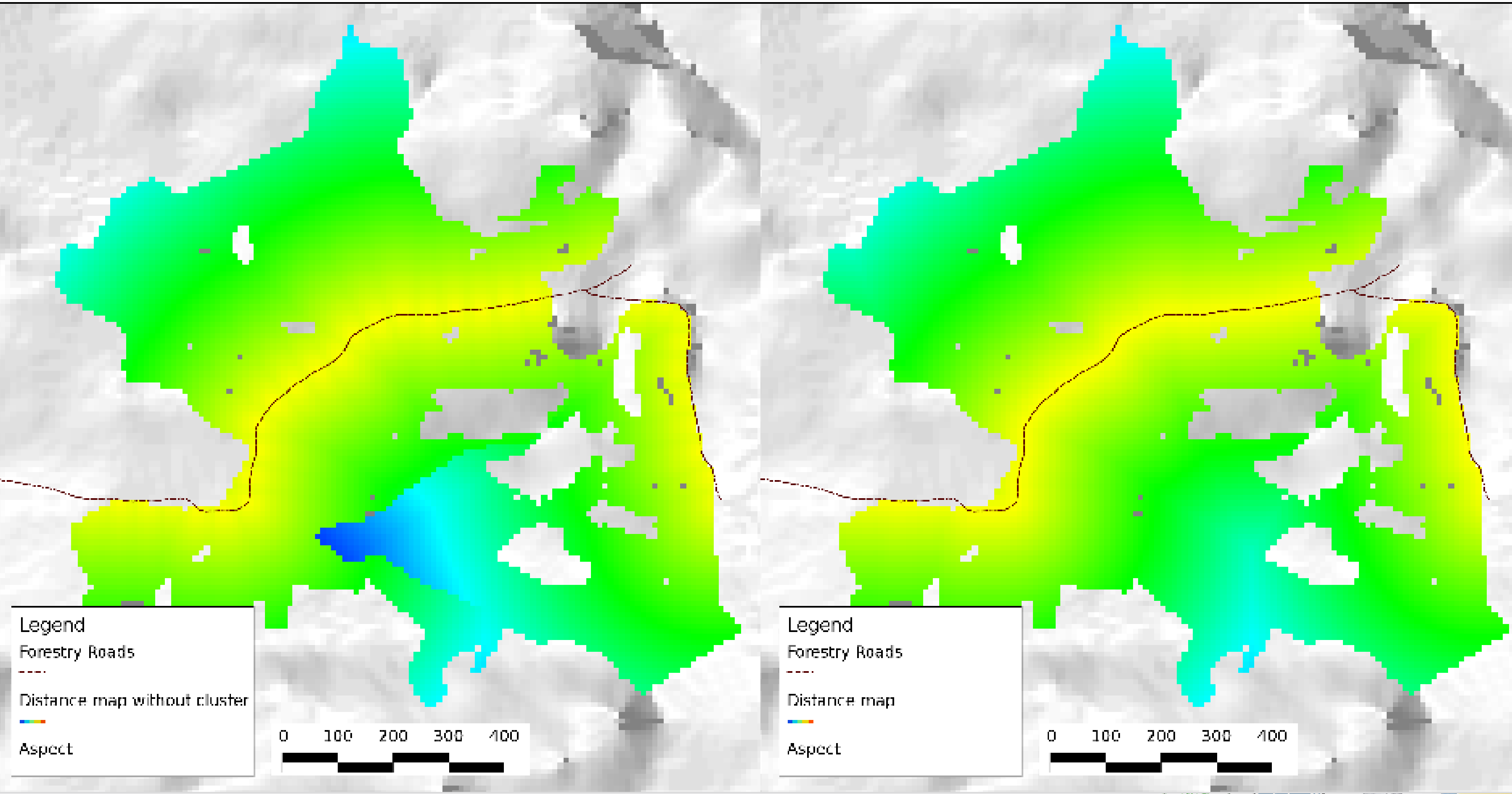
Identify roads points inside the buffer.

Harvester and Forwarder

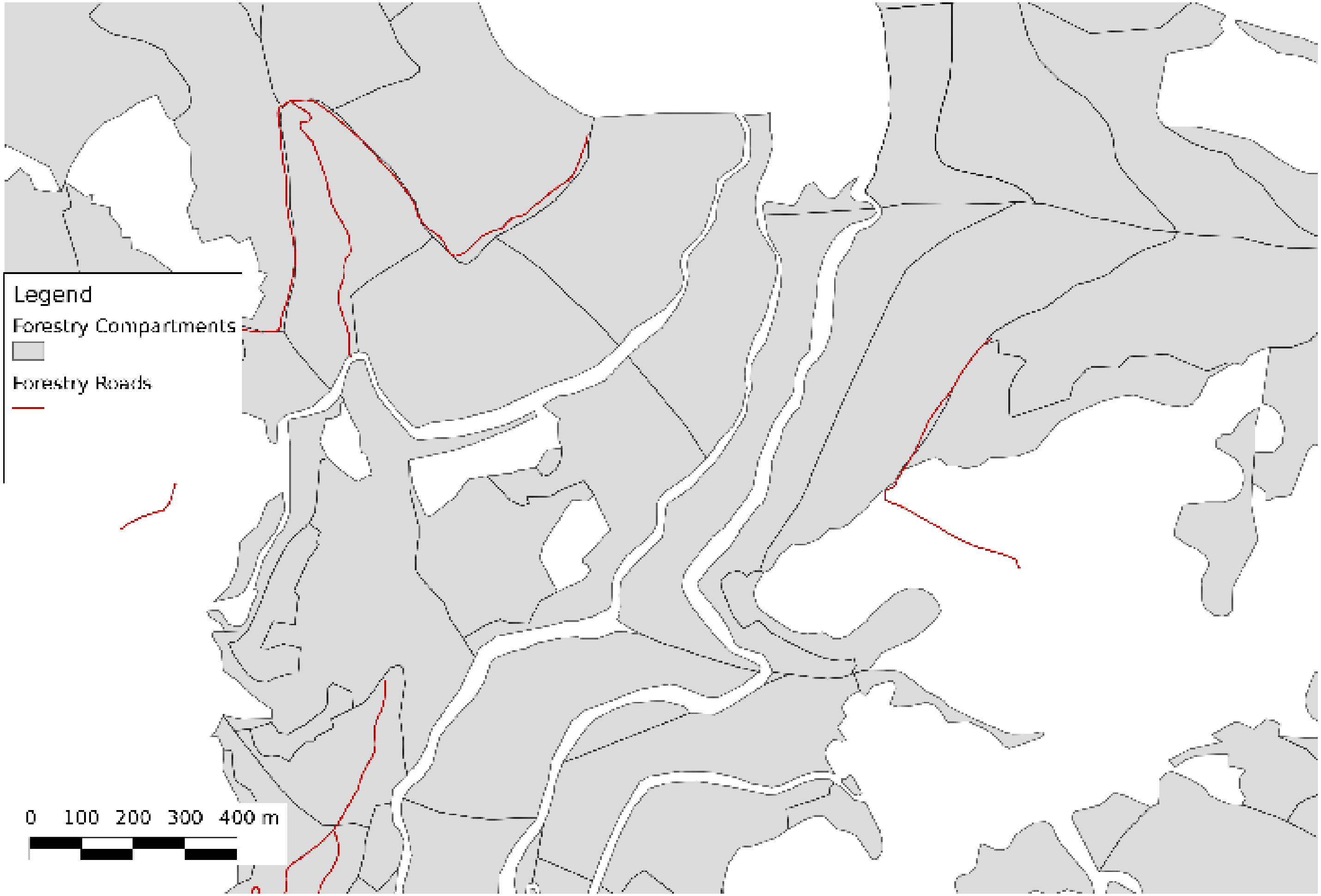


Calculate the distance and height for each pixel from the closest road point.

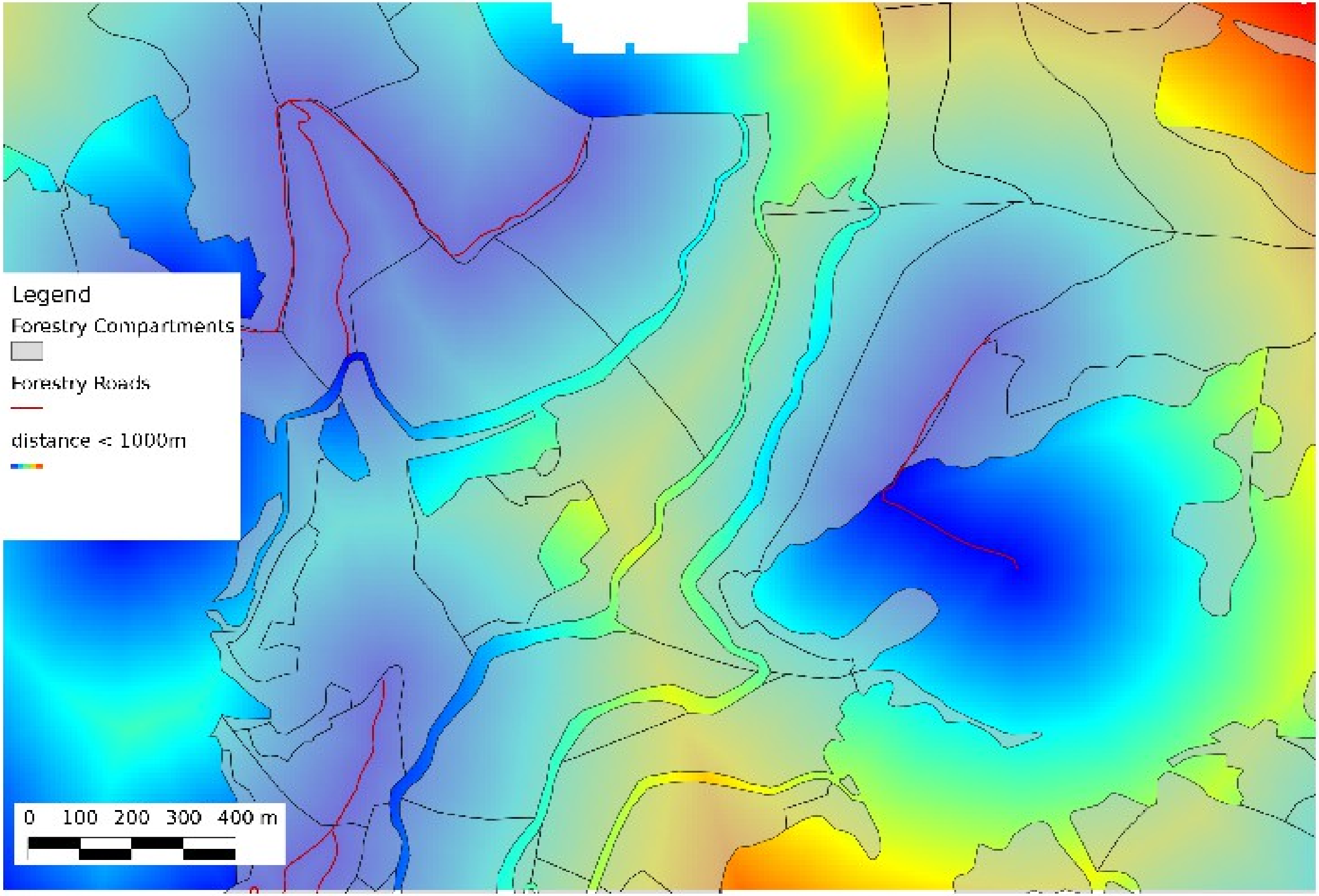
Cluster or no cluster?



Cable Crane

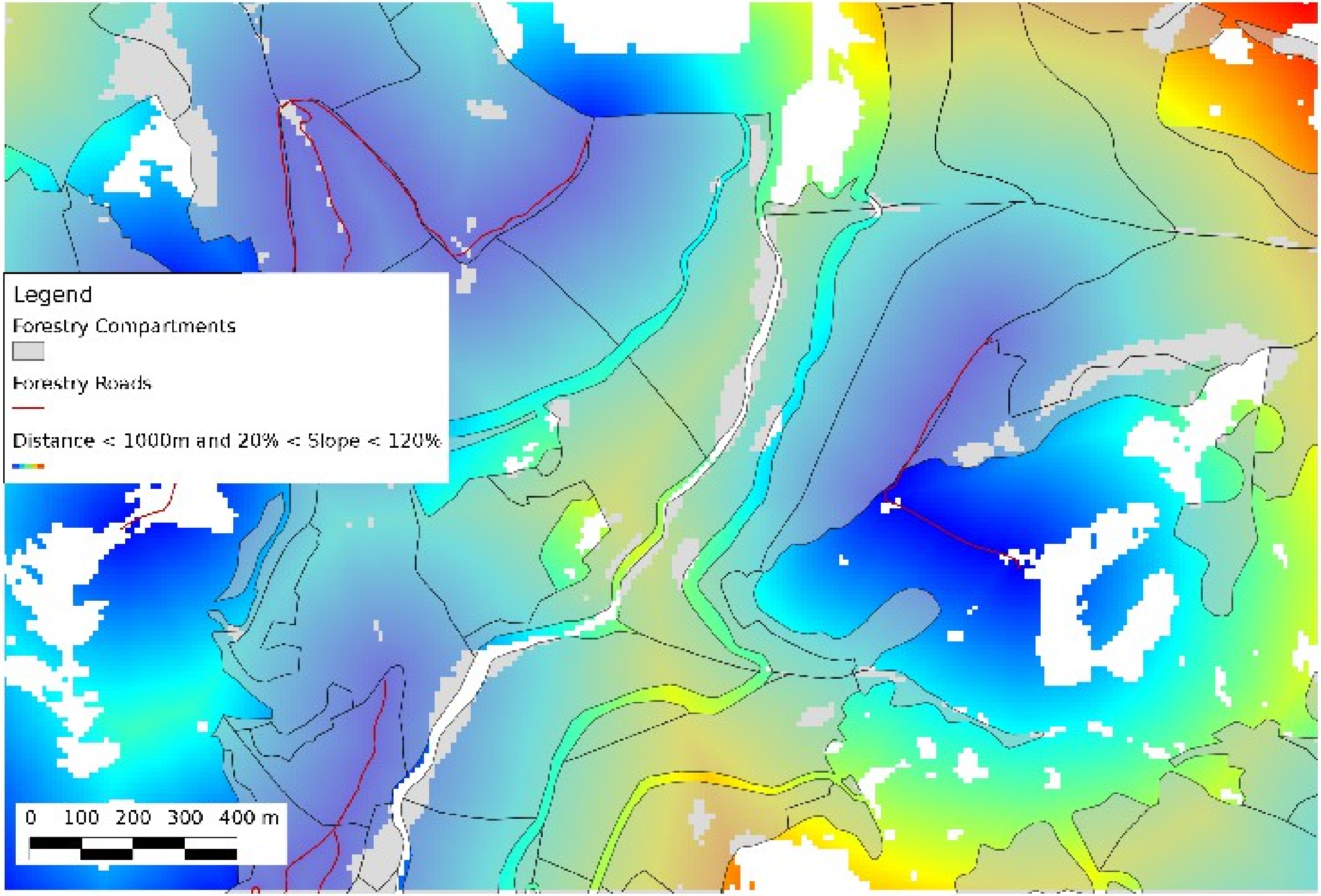

Legend
Forestry Compartments
Forestry Roads
0 100 200 300 400 m

Cable Crane



Calculate distance from forestry roads using r.cost

Cable Crane



Identify pixels with: 20% < slope < 120%

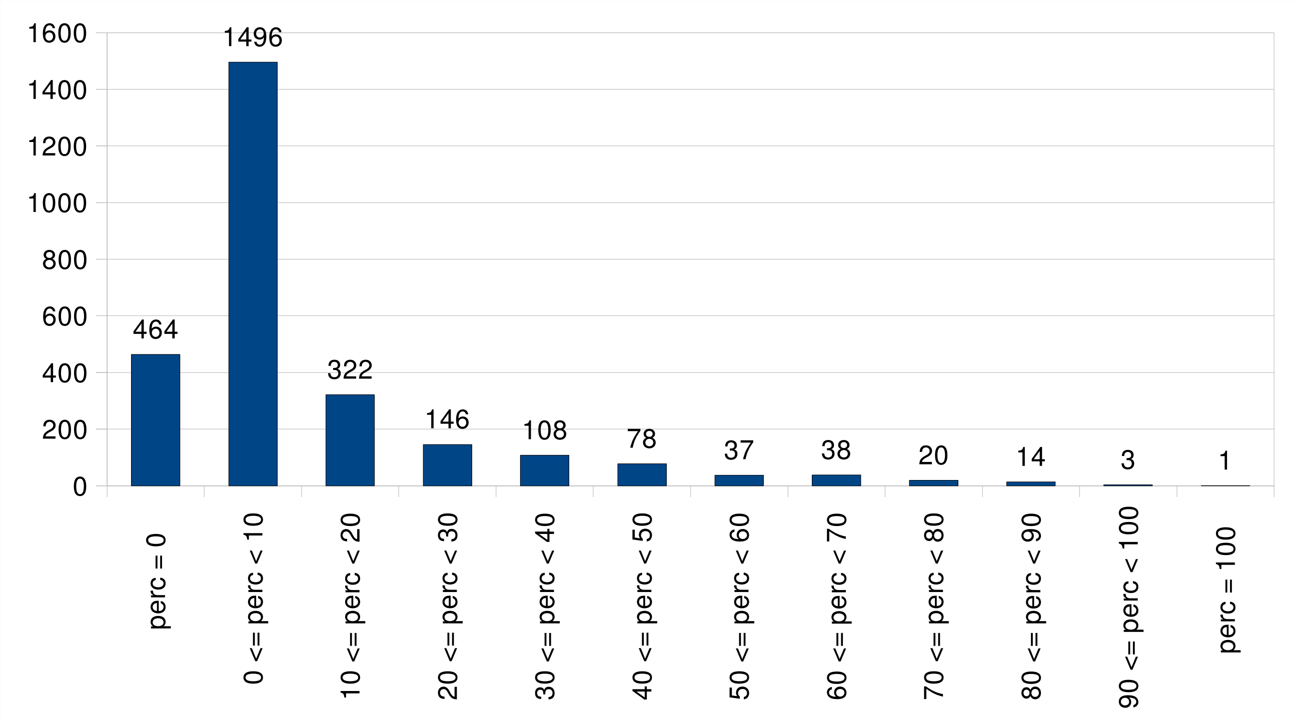
Biomass estimation

Once the exploitable area has been defined the biomass can be evaluated by:

1. Assessing the actual exploitable volume (m^3);
2. Transforming the volume to biomass expressed in tons.

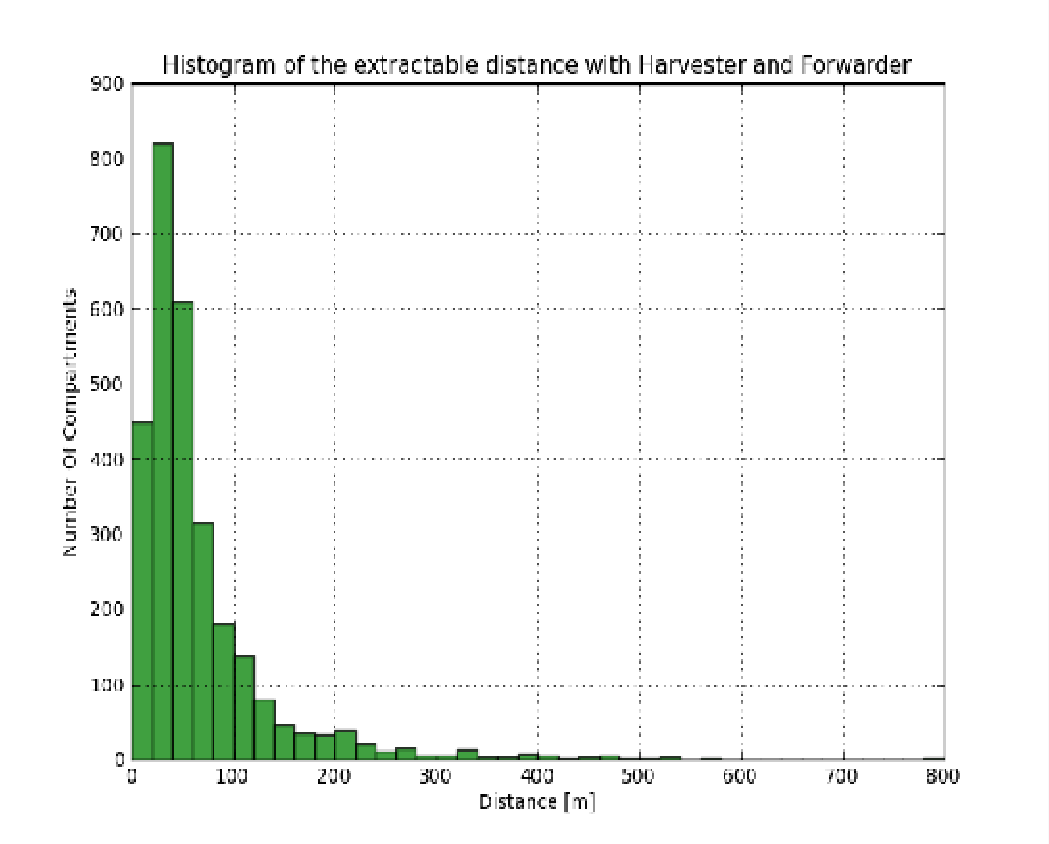
Model Results

- Evaluation of the total surface extractable with HF.



Model Results

- Distribution of the mean distance of the forest compartment to the nearest roads.



Model Results

- Extractable volumes of biomass, taking into account the different techniques.

	final yield [m³]	Method 1 hf [m³]	Method 1 cc [m³]	Method 1 total [m³]	Method 2 hf [m³]	Method 2 cc [m³]	Method 2 total [m³]
BORGO	38,493.0	1,367.5	35,958.8	37,326.2	5,752.0	32,741.0	38,493.0
CAVALESE	107,139.5	3,463.2	100,525.5	103,988.7	17,867.0	89,272.5	107,139.5
CLES	47,216.8	3,142.8	41,968.3	45,111.1	9,418.0	37,798.8	47,216.8
MALE'	46,588.5	1,285.5	43,929.7	45,215.2	6,486.2	40,102.3	46,588.5
PERGINE	64,125.5	1,264.4	61,039.0	62,303.4	5,727.4	58,398.1	64,125.5
PRIMIERO	54,527.9	1,748.9	51,036.4	52,785.3	8,922.9	45,605.0	54,527.9
RIVA	9,315.0	125.4	8,745.0	8,870.4	764.5	8,550.5	9,315.0
ROVERETO	13,134.0	908.4	11,248.7	12,157.1	3,372.1	9,704.6	13,076.7
TIONE	28,171.1	1,040.2	26,180.8	27,221.0	4,920.1	23,251.0	28,171.1
TRENTO	36,413.0	2,217.1	33,268.3	35,485.4	6,210.0	30,203.0	36,413.0
	445,124.3	*16,563.4*	*413,900.3*	*430,463.7*	*69,440.2*	*375,626.8*	*445,067.0*

Model Results

- Biomass conversion from volume to mass.

	Method 1			Method 2		
	hf	**cc**	**total**	**hf**	**cc**	**total**
Volume [m³]	*16,563.4*	*413,900.3*	*430,463.7*	*69,440.2*	*375,626.8*	*445,067.0*
optimistic assessment [ton] Spinelli	2,766.1	82,780.1	85,546.2	11,596.5	75,125.4	86,721.9
pessimistic assessment [ton] Spinelli	4,140.8	124,170.1	128,310.9	17,360.1	112,688.0	130,048.1
using volume table [ton] Pedrolli	2,882.8	72,037.3	74,920.1	12,085.7	65,376.0	77,461.7

Conclusions

- This work **is the first implementation** of a model able to estimate the available forest biomass for energy production in a given region **using FOSS4G software** mostly based on Grass and PostgreSQL-PostGIS.
- The purpose is to **balance simplicity and performance**, since few but representative data are required, and the whole process is **highly configurable**, making the application of the model to other regions possible.
- The FOSS4G model is able to estimate the available forest biomass for energy production with **reliable results**.
- The Forest biomass is a renewable energy source, an alternative to fossil fuel. The knowledge of its available amount and spatial distribution are fundamental information to achieve the emission reduction requirements defined by the **Kyoto** protocol.

Issues, future development

- The model could **over-estimate biomass amount, when** the prescribed volume **includes,** along with commercial volume, also the **volume used in local practices** (like "right of forest").
- To achieve a more accurate estimate of the actual energy amount **the specific heat could be characterized as a function of the forest stand**. This is one of the aims of the **Biomasfor Project**.
- The model could be also extended to consider the amount of biomass made available by thinnings.
- The source code must be improved and tested. The development version is available at:
  http://www.ing.unitn.it/~zambelli/ftp/biomasfor

  a stable version will be available at: http://www.ing.unitn.it/~grass/

Biomasfor Project

The BIOMASFOR project aims to evaluate the amount of this resource in the Trentino region (Italy) and, more important, to asses which part of biomass is actually extractable, given its quality and the energy needed to move it to the facilities where it is used.

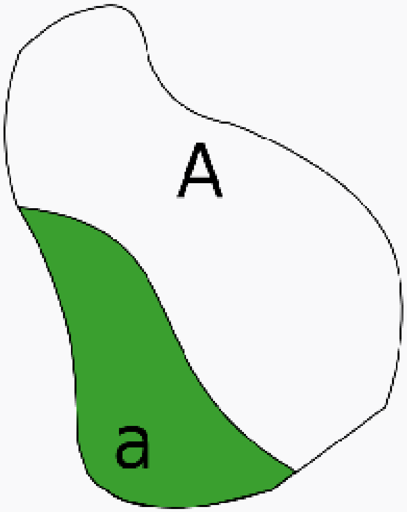
Co-finantied by:
Fondazione CARITRO

Partners:
- **FEM** Edmund Mach Foundation San Michele all'Adige (TN) Italy
- **DICA-UNITN** Dipartimento di Ingegneria Civile ed Ambientale - Università degli Studi di Trento, (TN) Italy
- **CRA-MPF** Unità di ricerca per il Monitoraggio e la Pianificazione Forestale, Consiglio per la ricerca e la Sperimentazione in Agricoltura, Villazzano (TN) Italy
- **CNR-IVALSA** Consiglio Nazionale per le Ricerche – Istituto per la valorizzazione del legno e delle Specie Arboree, Michele all'Adige (TN) Italy
- **SEAMK** - Seinäjoki University of Applied Sciences, Finland
- **BOKU** - Universität für Bodenkultur Wien, Institut für Forsttechnik, Vienna, Austria
- **FOBAWI** - Institut für Forstbenutzung und Forstliche Arbeitswissenschaft, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Thank you for your attention.

Questions?

Estimation of extractable volumes



Prescribed Cut = 80 m³

A = Total Area = 20 ha

a = Extractable Area = 2 ha

- Homogeneous final yield (Method 1)

a/A = 0.1 => ***Final Extract Volume*** = 80 m^3 • 0.1 = ***8 m³***

- Final yield rate per hectare (Method 2)

Final yield rate = 70 m^3/ha

Final Extract Volume = a • 70 m^3/ha = 140 m^3 > Prescribed cut => ***80 m³***

Biomass conversion from m^3 to tons

- Conversion based on empirical work

Type of cutting	Intensity of cutting [m³/ha]	Biomass [ton/ha]	Conversion factor [ton/m³]
Selection cutting (for HF)	60-80	10-20	0.167 - 0.250
Clear strip felling (for CC)	150-300	30-90	0.200 - 0.300

- Conversion based on volume table

Type of volume	Percentage in volume	Density [ton/m³]
Lop and top volume	16.30%	0.715
Bark volume	11.6%	0.5