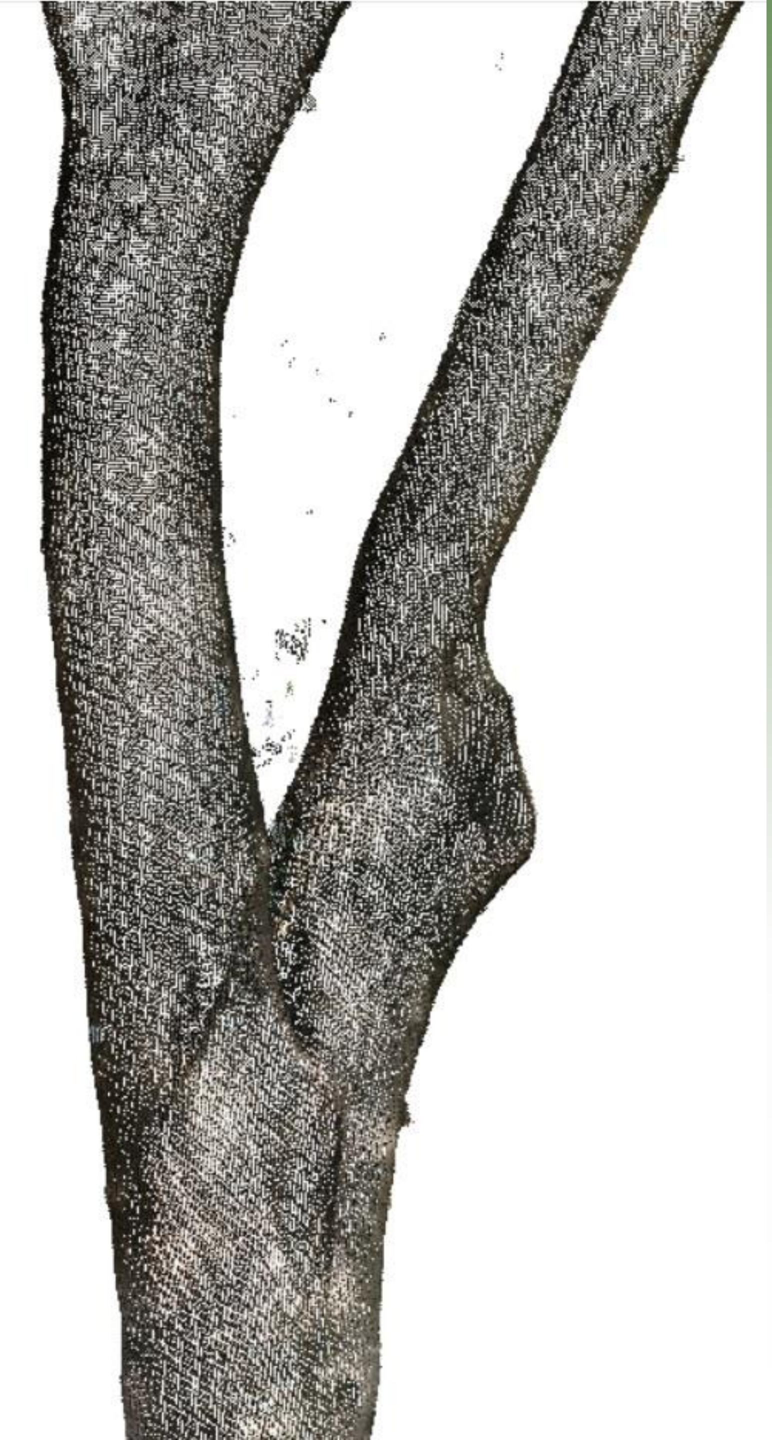


Estimação de parâmetros florestais com LiDAR uma introdução

Luiz Carlos Estraviz Rodriguez

Software

R + R Studio

(package LidR)

LAStools

Revisão das etapas

Preparação dos dados

Exercícios com TLS

Segmentação de dados TLS

Visualização

Etapas do processo ALS com R e LAStools

Conferir especificações
lasview
lasinfo
lasoverlap
lasvalidate

Arrumar as Nuvens -> LAZ
las2las
-epsg
-rescale
-set_classification

Quadricular com buffers
lastile
-tile_size 500
-buffer 30

Classificar solo e determinar as alturas dos pontos
lasground
-compute_height

Classificar vegetação e prédios
lasclassify
-step 3
-ground_offset 0.5

Classificar ruído
lasnoise
-ignore_class 2
-step 2
-isolated 3
-classify_as 1

…

…

Criar quadrículas limpas
lastile
-drop_class 1
-remove_buffer

Criar nuvem para cada área área interesse
lasclip
-merged
-poly
-split

Produzir mapas DTM DSM
blast2dem
-keep_class 2

-keep_class 2 5

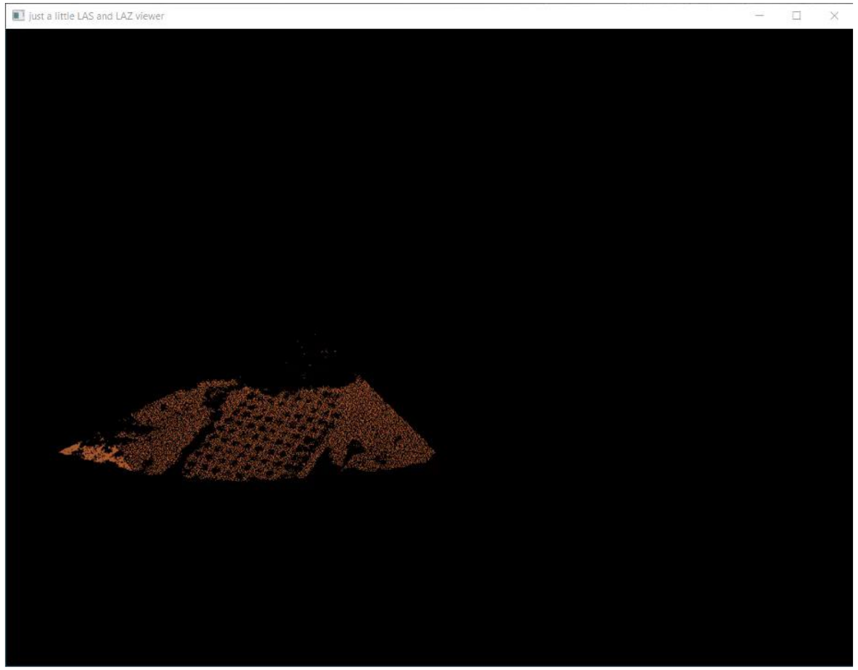
Normalizar quadrículas
lasheight
-replace_z
-set_user_data 0

Calcular métricas LiDAR
lascanopy
-drop_class 1
-step 20
-centroids
-height_cutoff 0.5
-cover_cutoff 0.5

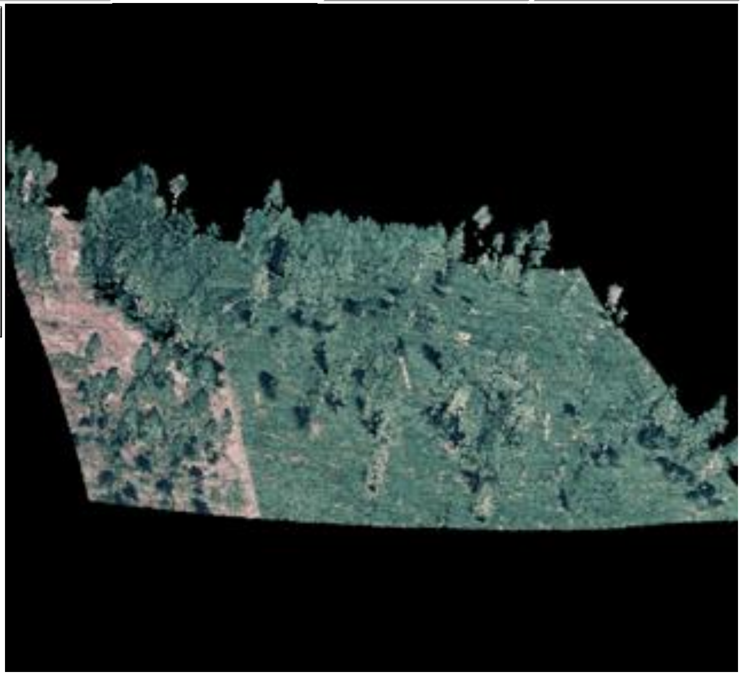
Inferir e produzir mapas

Etapas do processo **ALS** com **R e LAStools**

Conferir especificações



LAStools



Outros sistemas úteis:

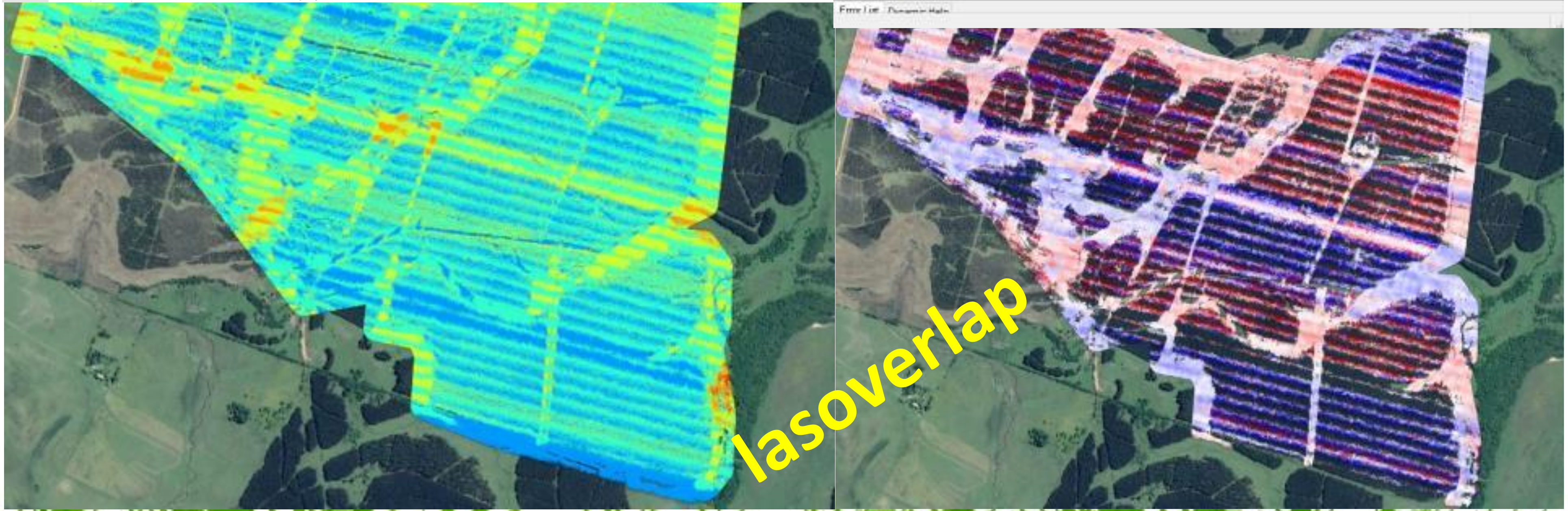
- potree
- LidR
- SAGA GIS
- MCC-LiDAR

Etapas do processo **ALS** com **R e LAStools**

Conferir especificações

lasinfo

```
reporting all LAS header entries:
...
  system identifier:           'LAStools (c) by rapidlasso GmbH'
  generating software:         'lasmerge (version 161114)'
  file creation day/year:      315/2016
  header size:                 227
  offset to point data:        227
...
  number of point records:     441270594
...
covered area in square units/kilounits: 3991672/3.99
point density: all returns 110.55 last only 99.68 (per square units)
      spacing: all returns 0.10 last only 0.10 (in units)
overview over number of returns of given pulse: 355001767 86268827 0 0 0 0 0
histogram of classification of points:
       121911915  never classified (0)
        14668361  ground (2)
       304305141  high vegetation (5)
          366835  building (6)
           18342  noise (7)
```



Etapas do processo ALS com R e LAStools

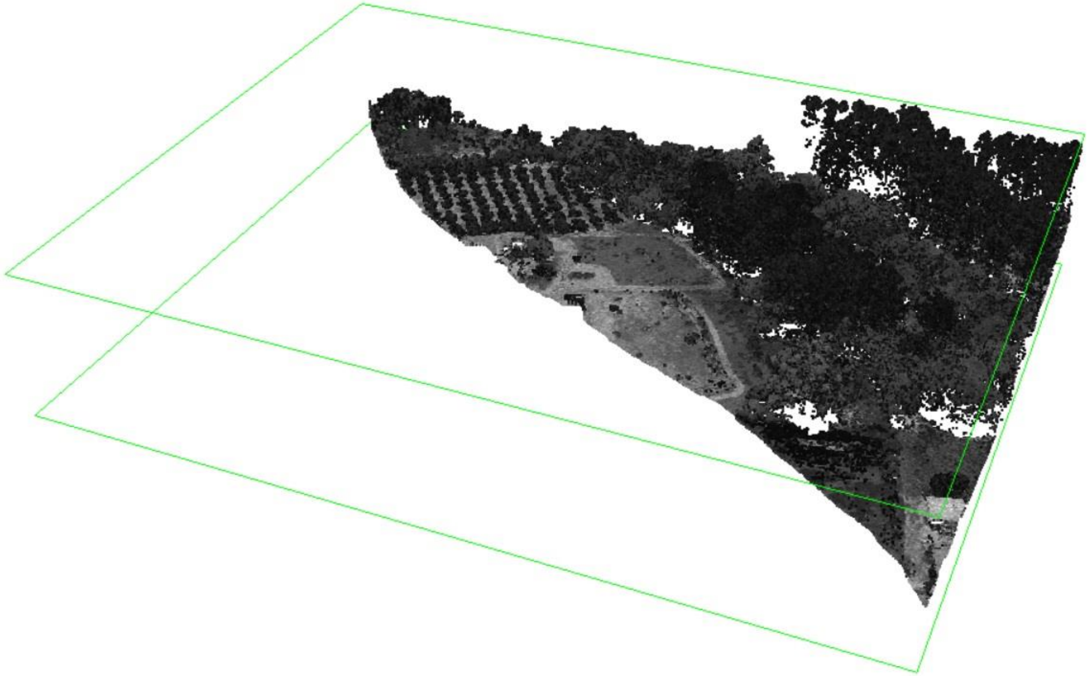
Arrumar nuvens

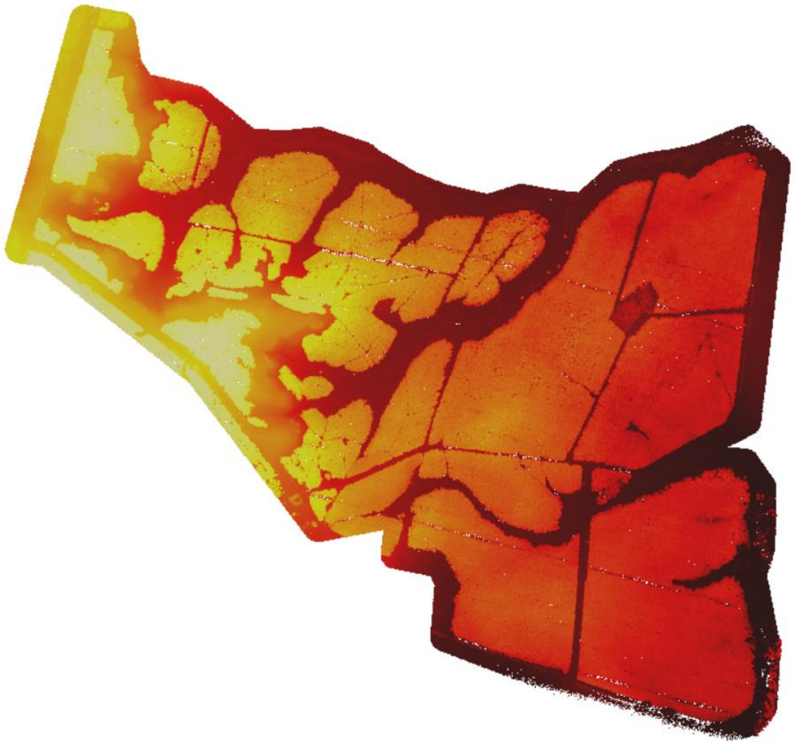
LAS version: 1.2
source ID: 0 created: 315/2016
'LAStools (c) by rapidlasso GmbH'
'las2las (version 170628)'
# of points: 441270588
point type: 1 point size: 28
x: 485424.95 488197
y: 6402583.94 6405189.54
z: 77.54 170.62
compression: LASzip 3.0r1 50000

# of VLRs: 0
global_encoding: 0
header size: 227 offset: 227
# of 1st returns: 398394041
# of 2nd returns: 42876547
# of 3rd returns: 0
# of 4th returns: 0
# of 5th returns: 0
offset x y z: 400000 6400000 0
scale x y z: 0.01 0.01 0.01

WGS 84 / UTM 21S
horizontal meter
vertical meter

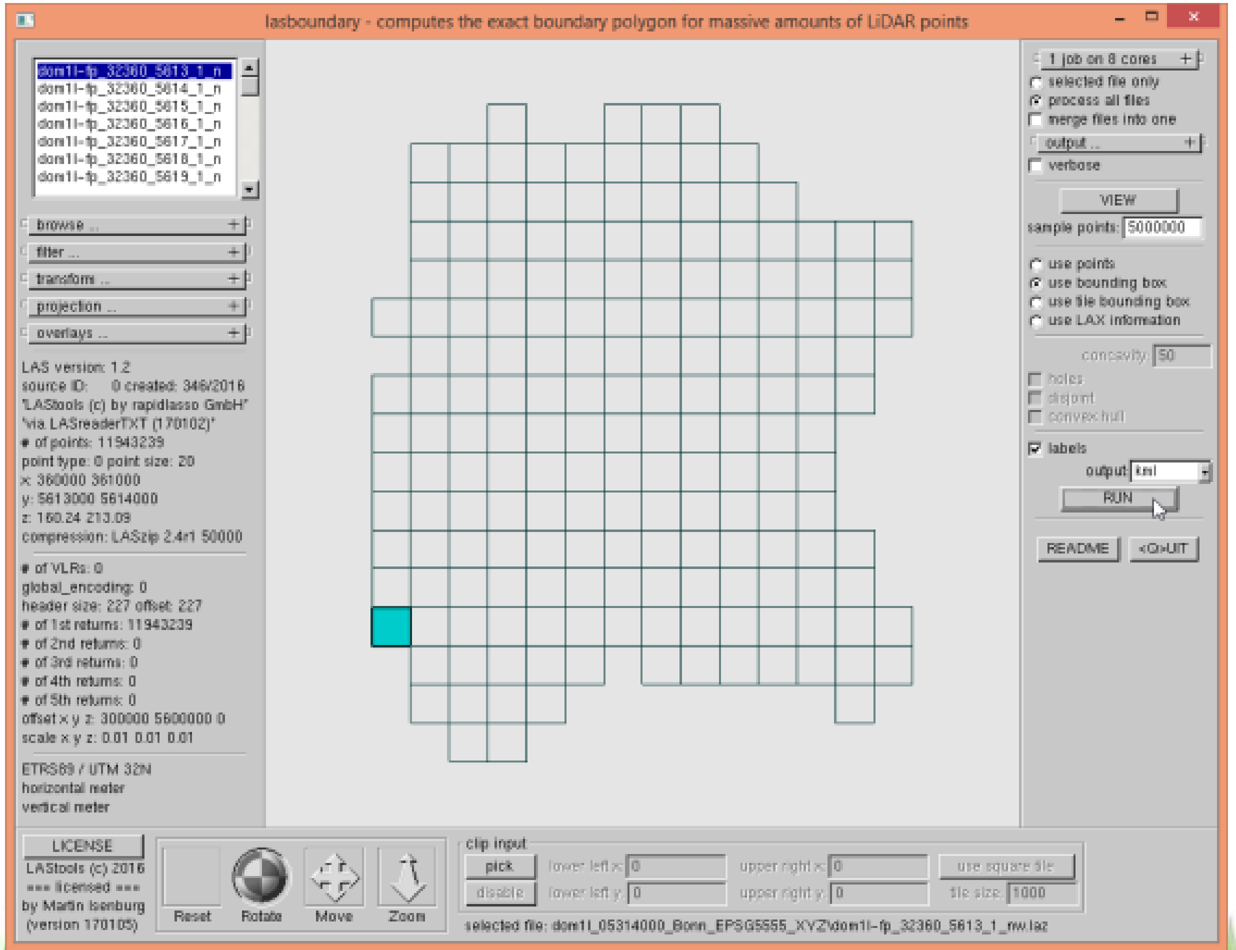
LICENSE
LAStools (c) 2017
=== licensed ===
by Martin Isenburg
(version 170628)





Etapas do processo ALS com R e LAStools

Quadricular

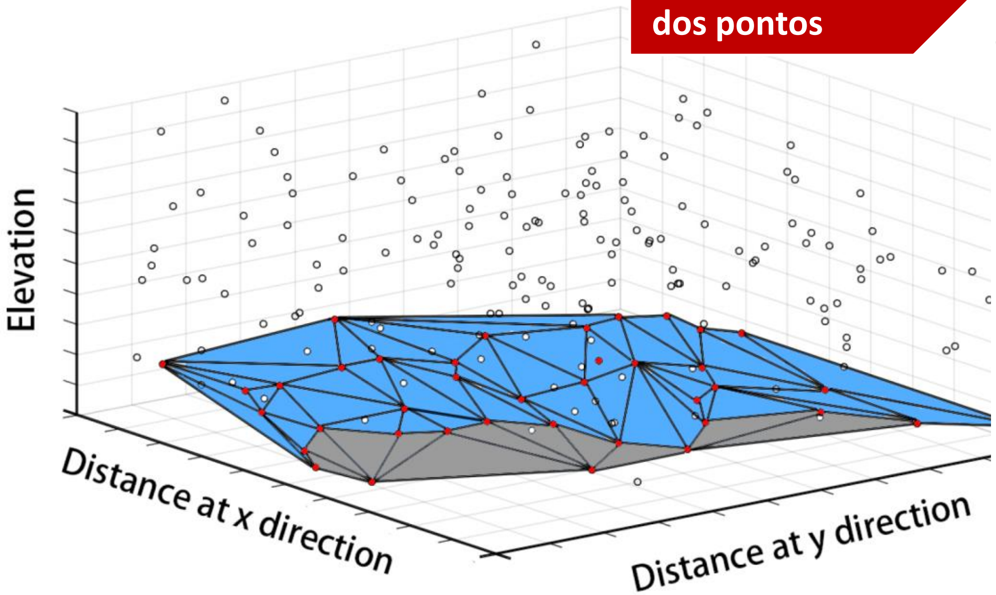


lastile

-tile_size 500
-buffer 30

Etapas do processo ALS com R e LAStools

Definir solo e determinar alturas dos pontos



ELSEVIER

ISPRS Journal of Photogrammetry & Remote Sensing 53 (1998) 193–203

PHOTOGRAMMETRY & REMOTE SENSING

Determination of terrain models in wooded areas with airborne laser scanner data

K. Kraus *, N. Pfeifer

Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Gusshausstr. 27–29, 1040 Vienna, Austria

International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B4. Amsterdam 2000.

DEM GENERATION FROM LASER SCANNER DATA USING ADAPTIVE TIN MODELS

Peter Axelsson
Digpro AB
Ynglingagatan 14
113 47 Stockholm, Sweden

Etapas do processo ALS com R e LAStools

Definir solo e determinar alturas dos pontos

Sensors 2017, 17, 150; doi:10.3390/s17010150 www.mdpi.com/journal/sensors

sensors

Kraus and Pfeifer (FUSION)

MDPI

Review

State-of-the-Art: DTM Generation Using Airborne LIDAR Data

Ziyue Chen [1,*], Bingbo Gao [2] and Bernard D

1 College of Global Change and Earth System S
Beijing 100875, China
2 Beijing Research Center for Information Tech
Forestry Sciences, Beijing 100097, China; gaob
3 Department of Geography, University of Can
* Correspondence: zychen@bnu.edu.cn; Tel.: +8

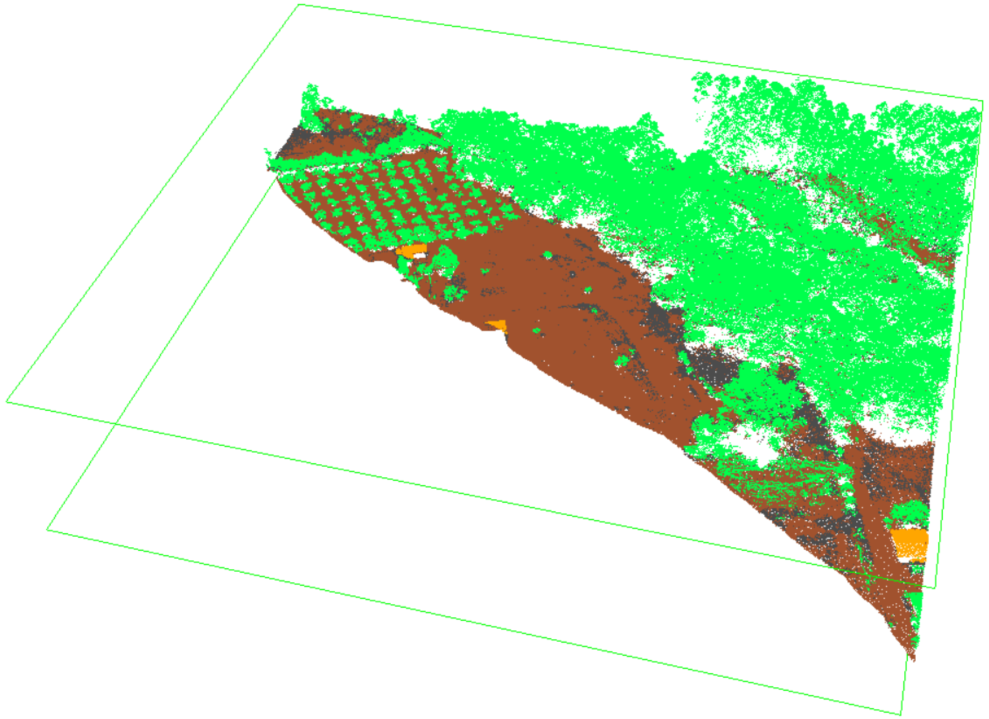
The most widely used Lidar processing software ***TerraScan**** *was designed based on the* ***Axelsson's*** *TIN-model … and the reliability and accuracy of this method has been proved by a large body of studies.*

** também usado no* ***LAStools***

Filtering Methods	Suitable for	Not Suitable for	Memory Storage Demands	Computational Efficiency [2]
Surface-based	Forested areas	Rough and steep terrains	High	Middle
Morphology-based	Steepterrains [1], Terrains with small objects	Terrains with various objects	Low	High
TIN-based	Steep terrains	Urban areas, Discontinuous terrains	Middle	Middle
Segmentation-based	Urban areas, Terrains with various objects	Rough and steep terrains, Dense forests	NA [3]	NA [4]
Statistical analysis	Generally flat terrains	Terrains with various objects	Low	Low
Multi-scale comparison	Urban areas	Rough and steep terrains	Middle	Low

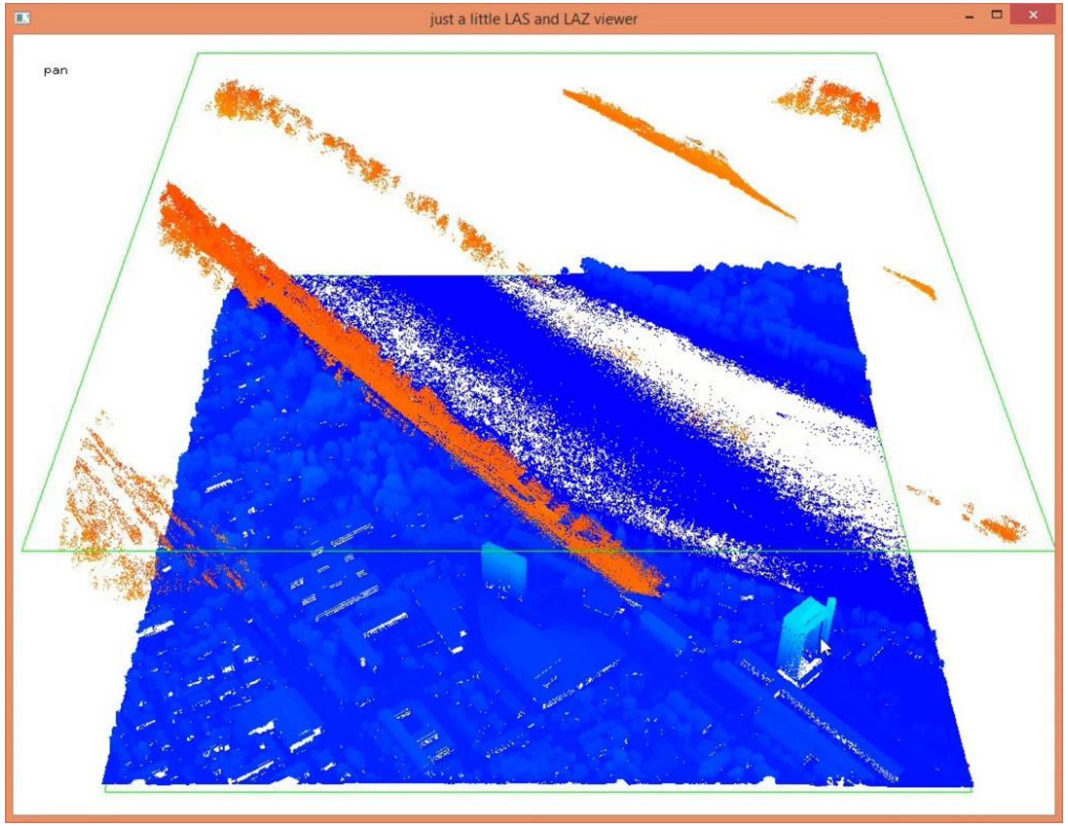
Etapas do processo ALS com R e LAStools

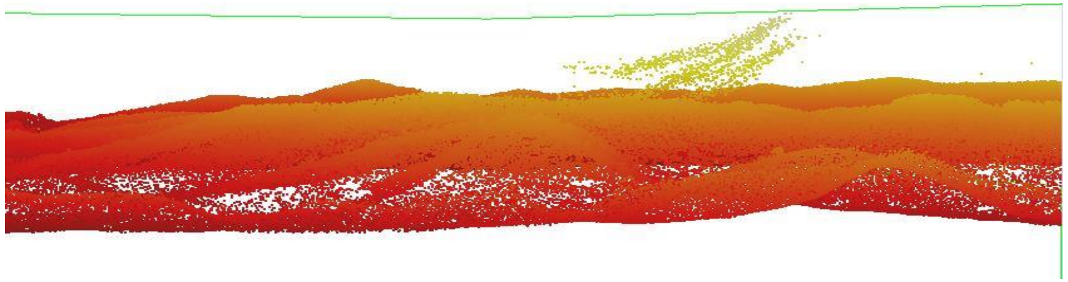
Classificar vegetação e prédios



Etapas do processo ALS com R e LAStools

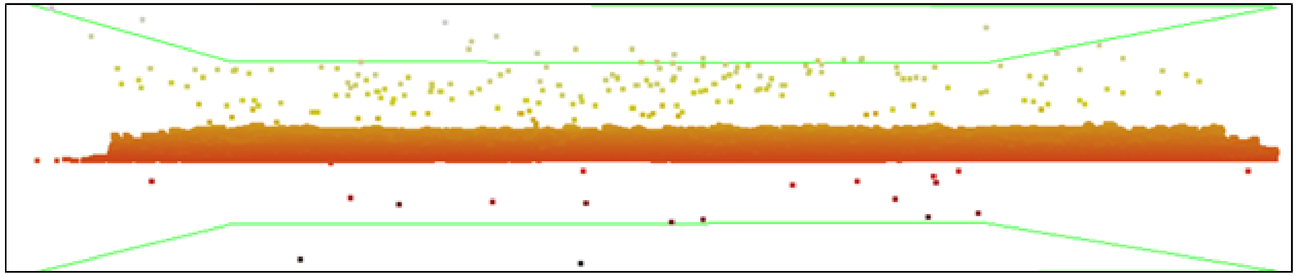
Classificar ruído

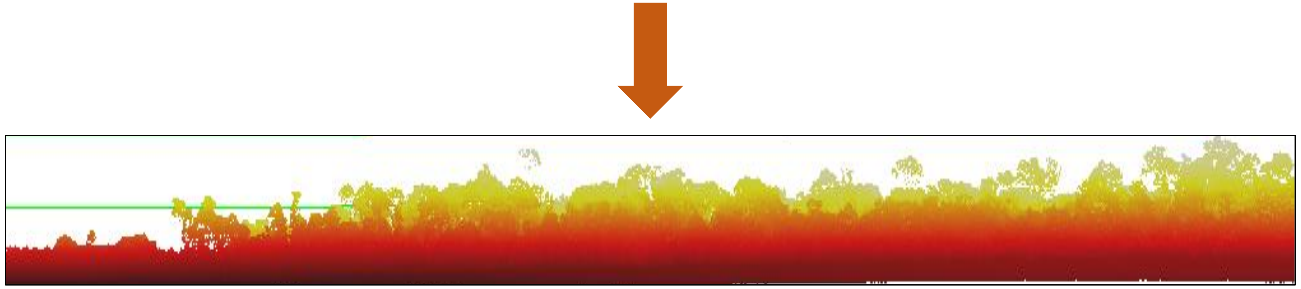


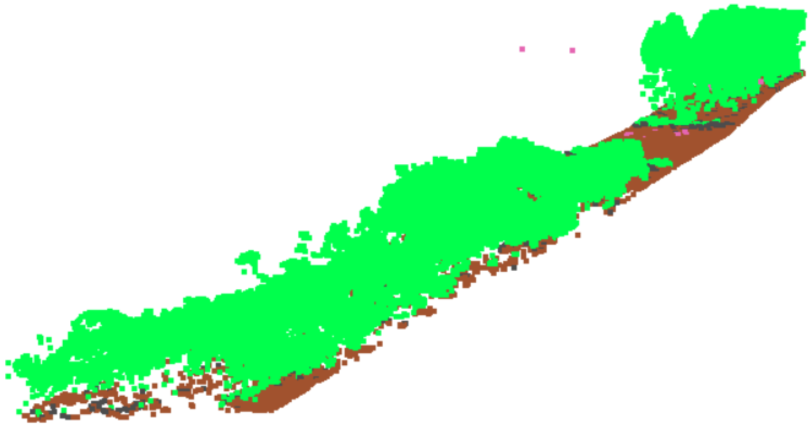


Etapas do processo ALS com R e LAStools

Quadrículas limpas



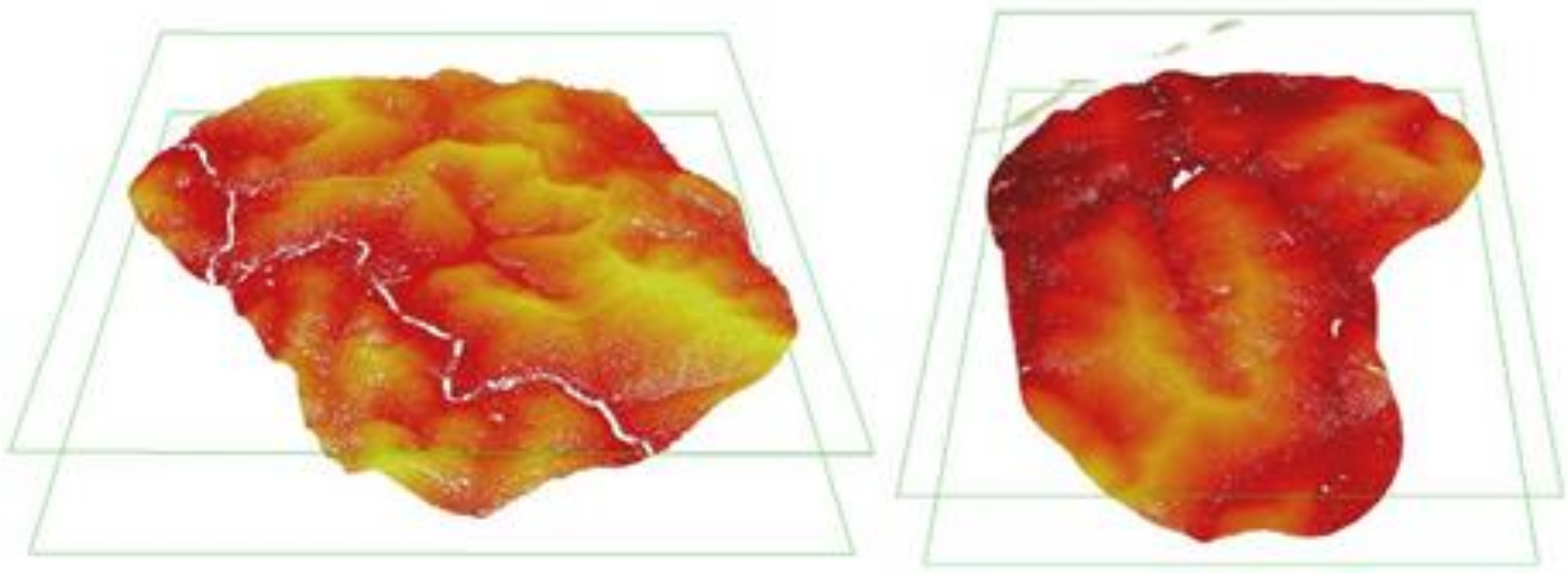




```
LASrun = LAStool('lasnoise', inDir,
         '-cores', cores,
         '-ignore_class 2',
         '-step 4',
         '-isolated 5',
         '-odir', outDir,
         '-odix _d',
         '-olaz -v')
```

Etapas do processo **ALS** com **R e LAStools**

Criar nuvem para cada área de interesse



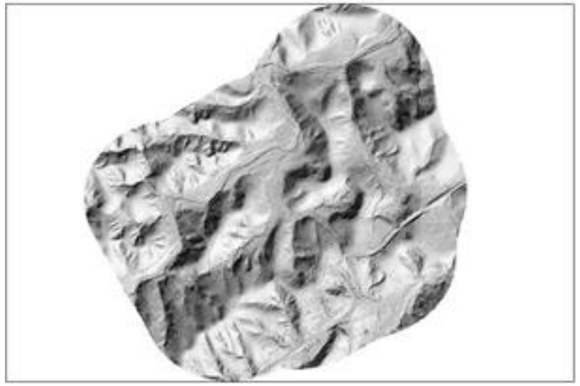
```
LASrun = LAStool('lasclip', inDir,
            '-merged',
            '-poly', inShp,
            '-split CUADRO',
            '-odir', outDir,
            '-olaz',
            '-v')
```

Etapas do processo ALS com R e LAStools

Produzir mapas DTM e DSM

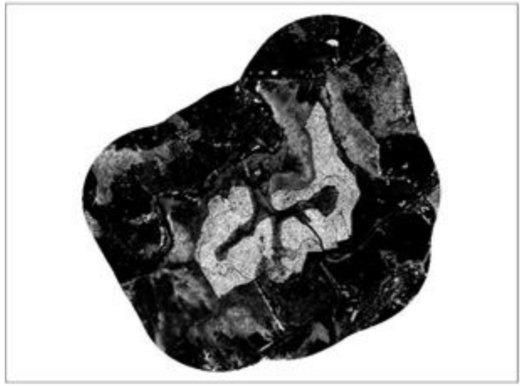
DTM (elevación del terreno)

```
LASrun = LAStool('blast2dem', inDir,
        '-keep_class 2',
        '-step 1',
        '-elevation',
        '-hillshade',
        '-odir', outDir,
        '-odix _dtm',
        '-opng -v')
```



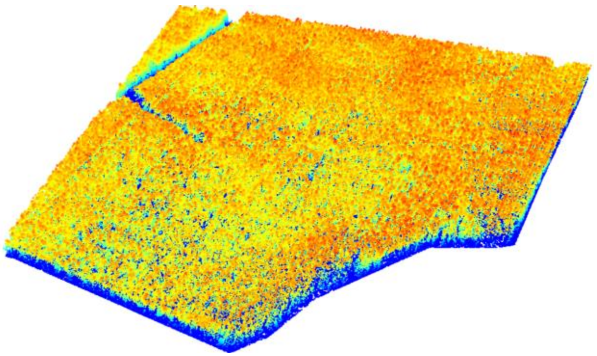
DSM (elevación del terreno + vegetación)

```
LASrun = LAStool('blast2dem', inDir,
        '-keep_class 2 5',
        '-step 1',
        '-elevation',
        '-hillshade',
        '-odir', outDir,
        '-odix _dsm',
        '-opng -v')
```



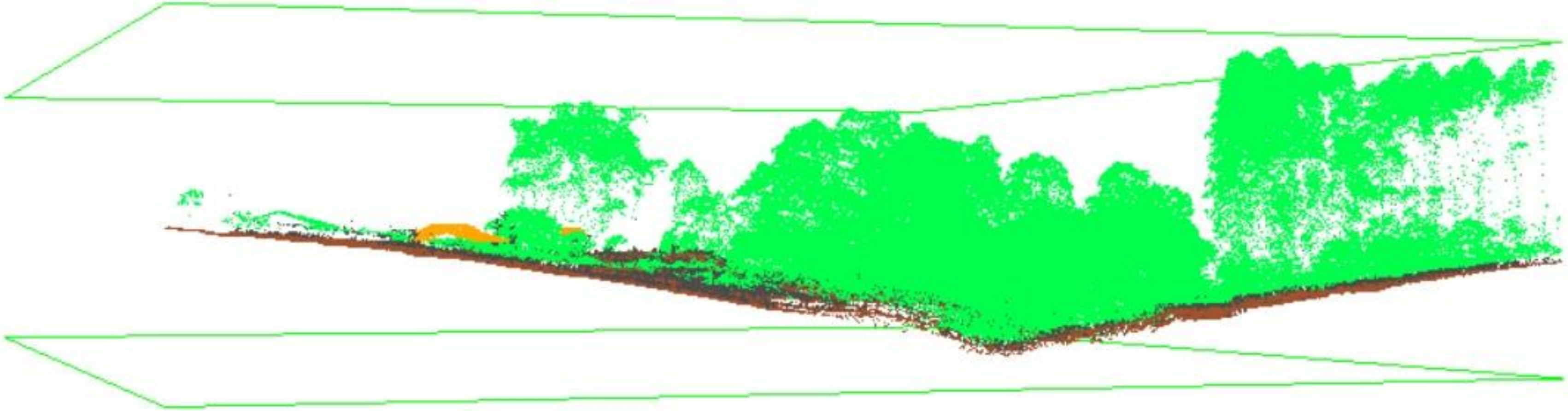
DEM (elevación solo de la vegetación)

```
LASrun = LAStool('lasgrid', inDir,
        '-user_data',
        '-step 1',
        '-false',
        '-odir', outDir,
        '-odix _dem',
        '-opng -v')
```

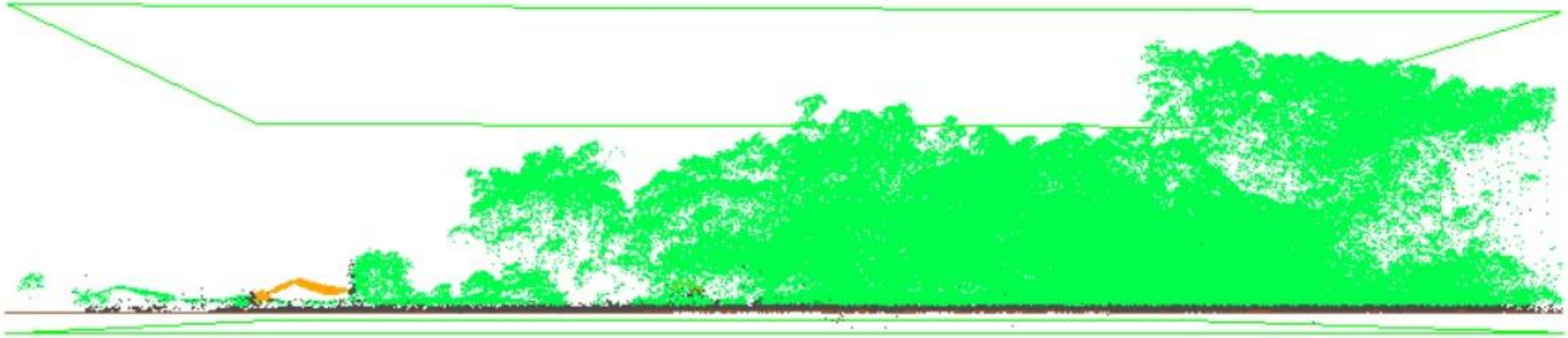


Etapas do processo ALS com R e LAStools

Normalizar quadrículas



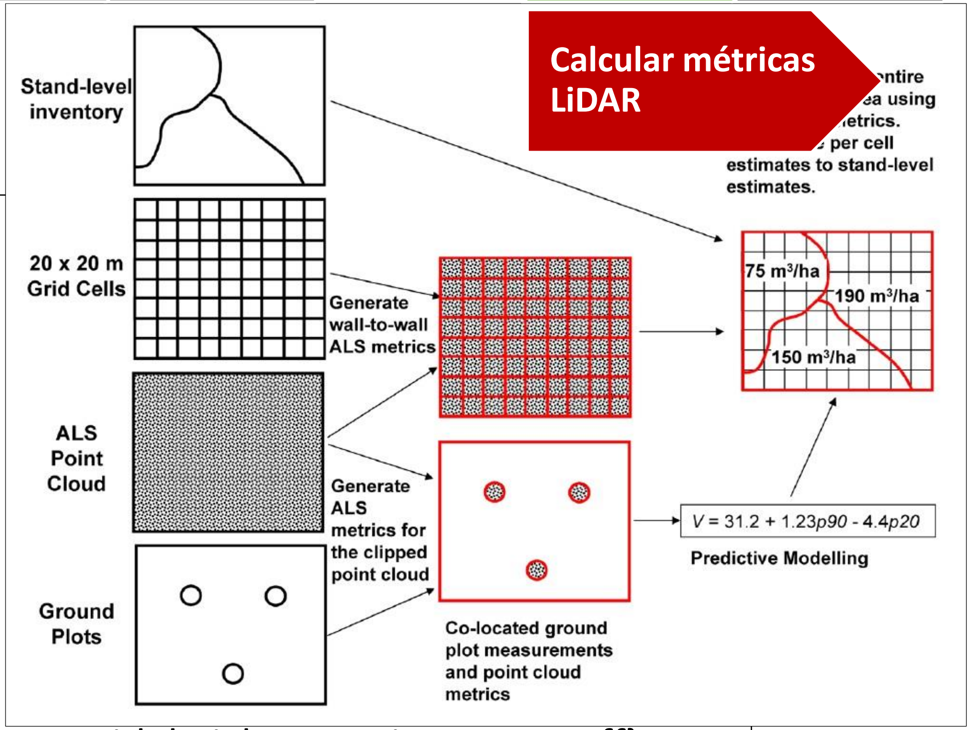
```
LASrun = LAStool('lasheight', inDir,
                 '-cores', cores,
                 '-replace_z',
                 '-set_user_data 0',
                 '-odir', outDir,
                 '-odix _n',
                 '-olaz -v')
```



Etapas do processo ALS com R e LAStools

Calcular métricas LiDAR

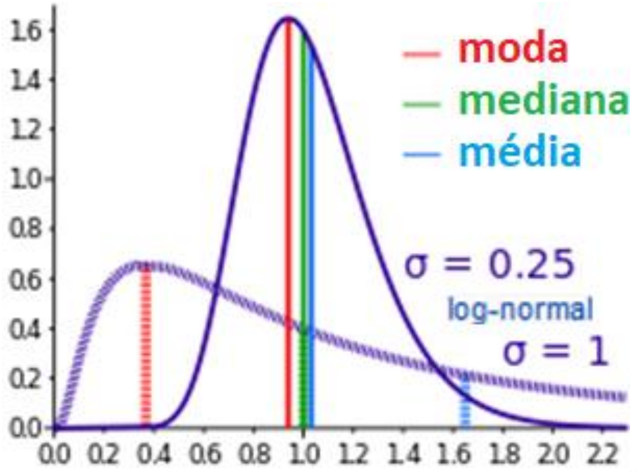
Métricas para o grid da área de estudo

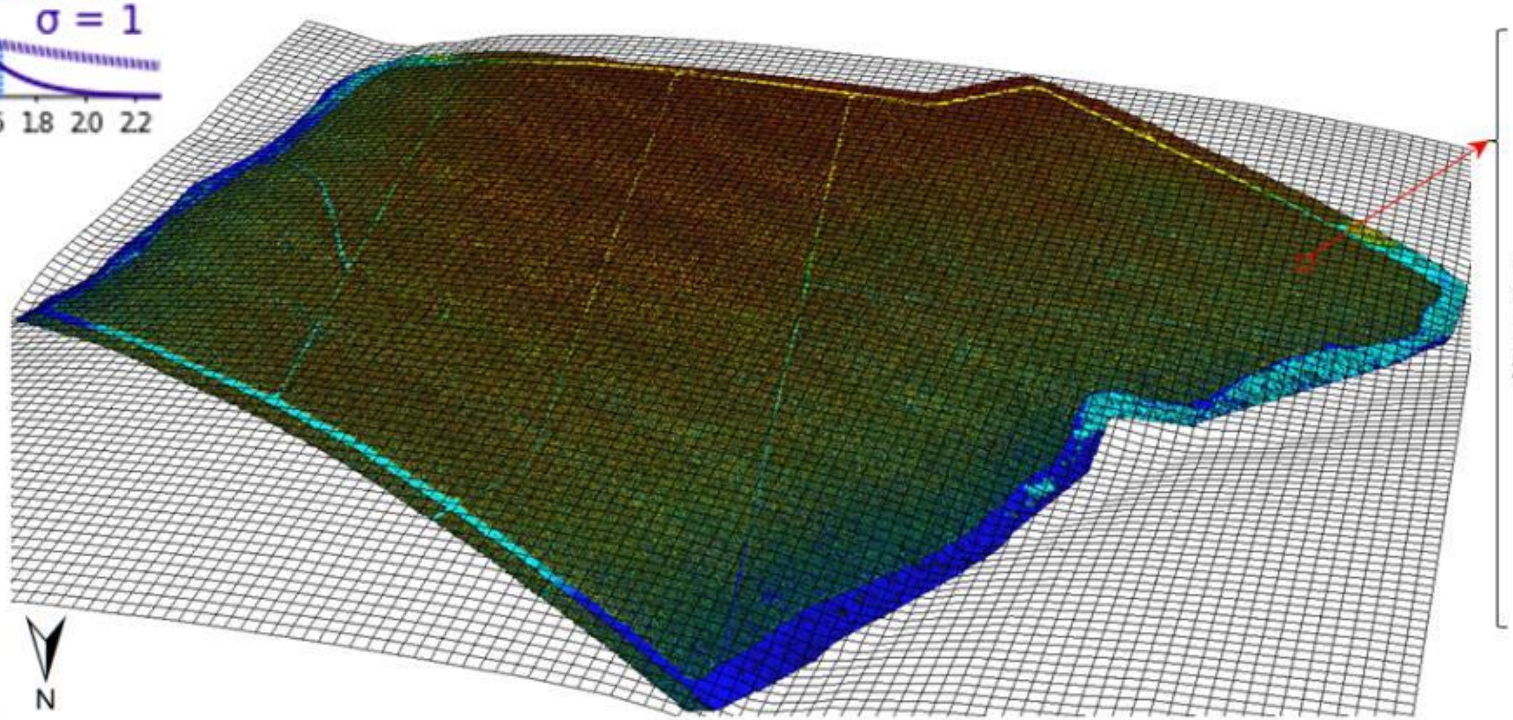


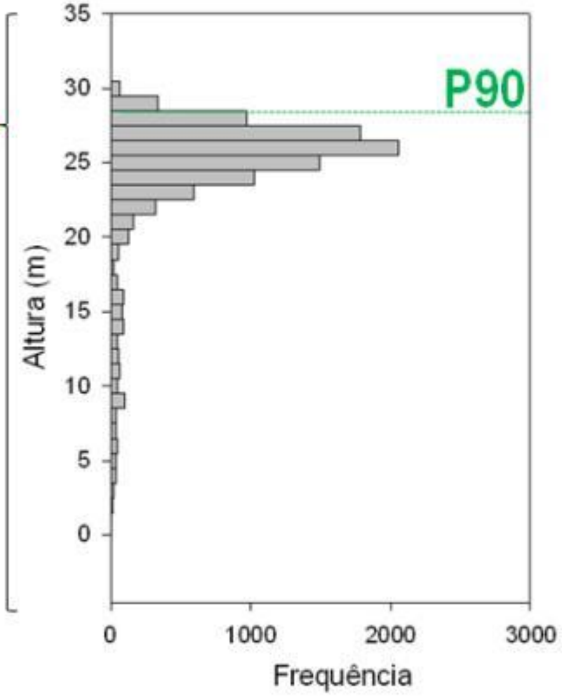

```
LASrun = LAStool('lascanopy', inDir,
        '-merged',
        '-keep_z 0.0 40.0 -drop_class 1',
        '-step ', cell_size,
        '-grid_ll 10 10',
        '-height_cutoff 0.5',
        '-cover_cutoff  1.3',
        '-max -avg -std -ske -kur -qav',
        '-cov',  # canopy cover (%) first returns above the cover cutoff / all first returns
        '-dns',  # (%) all returns above the cover cutoff   / all returns
        '-b 25 50 75', # points in the lower 25% "voxel" / "points in the voxel" {voxel: column with height = maximum - cutoff}
        '-c 0.5 1.3 10.0 20.0 35.0', # amount of points whose heights fall into the intervals
        '-d 0.5 1.3 10.0 20.0 35.0', # (%) points with heights into the intervals / total
        '-p 10 30 70 90',       # percentiles 10, 30, 70 and 90
        '-odir', outDir,
        '-o AtClip2016.asc',
        '-oasc -v')
```

Etapas do processo ALS com R e LAStools

Calcular métricas LiDAR







Etapas do processo ALS com R e LAStools

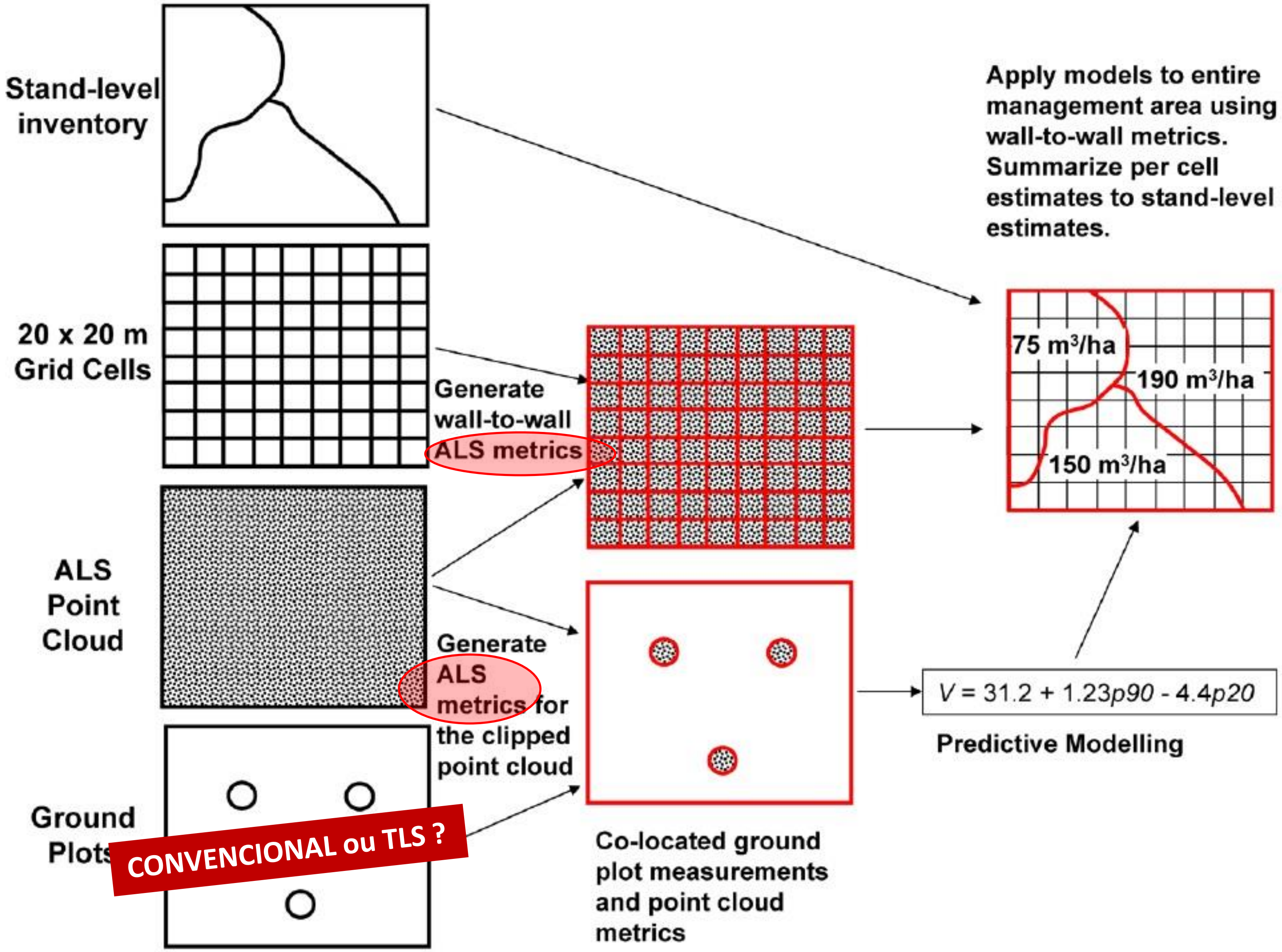
Calcular métricas LiDAR

Métricas de altura e cobertura de copa derivadas do LiDAR.

Category	LiDAR metric	Acronym
Height	Maximum Height	h_{max}
	Mean height	h_{mean}
	Standard deviation of mean height	h_{sd}
	Coefficient of variation of height	h_{cv}
	Mode of height	h_{mod}
	5th percentile of height	H5
	10th percentile of height	h10
	20th percentile of height	h20
	25th percentile of height	h25
	30th percentile of height	h30
	40th percentile of height	h40
	50th percentile of height	h50
	60th percentile of height	h60
	70th percentile of height	h70
	75th percentile of height	h75
	80th percentile of height	h80
	90th percentile of height	h90
	95th percentile of height	h95
	99th percentile of height	h99
Cover	Percentage of first returns above 2 m	C_{dens}

Etapas do processo ALS com R e LAStools

Inferir e produzir mapas

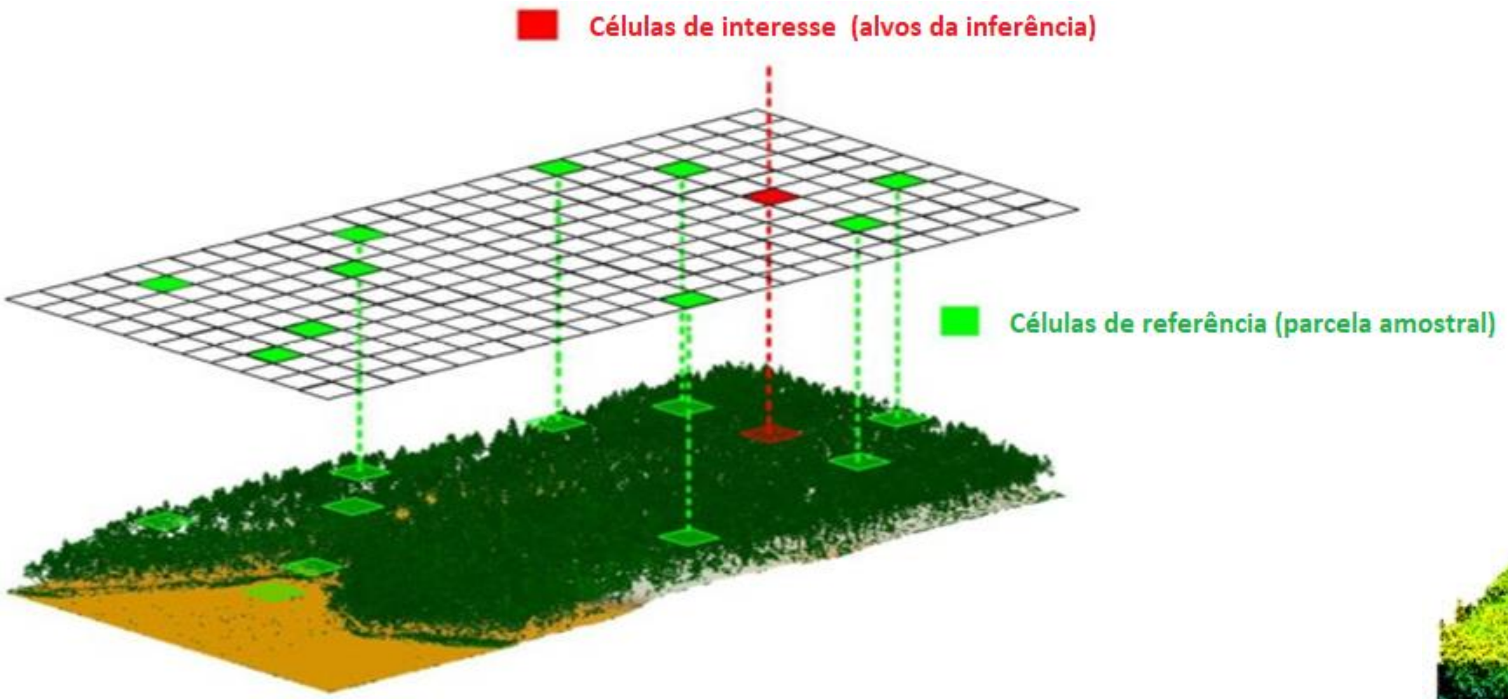


Joanne C. White; Michael A. Wulder; Andrés Varhola; Mikko Vastaranta; Nicholas C. Coops; Bruce D. Cook; Doug Pitt and Murray Woods.

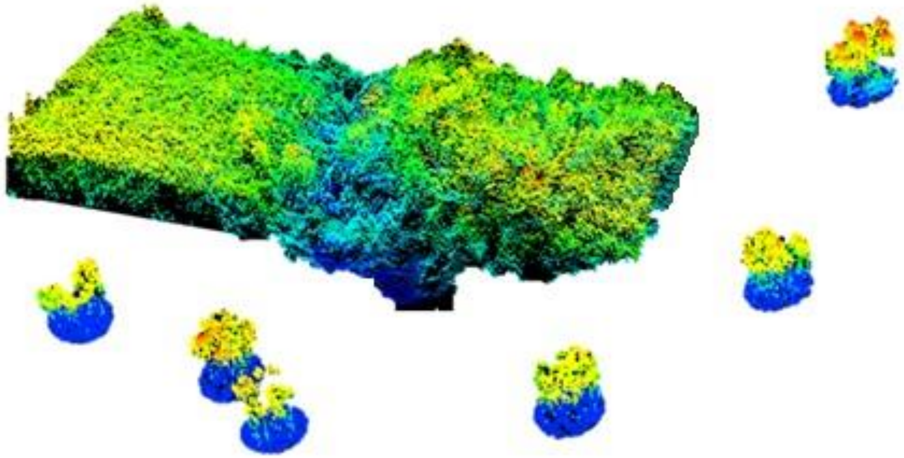
A best practices guide for generating forest inventory attributes from airborne laser scanning data using an area-based approach (Version 2.0) Natural Resources, Canadian Forest Service, Canadian Wood Fibre Centre. Information Report FI-X-010, 2013.

Etapas do processo ALS com R e LAStools

Inferir e producir mapas



CONVENCIONAL ou TLS ?



Etapas do processo ALS com R e LAStools

Calcular métricas LiDAR

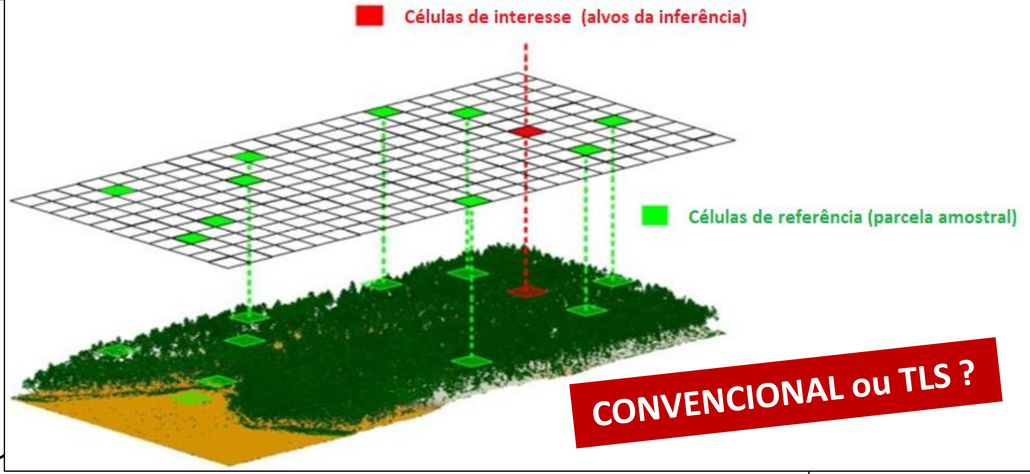
Métricas para as parcelas

1

```
LASrun = LAStool('lasclip', inDir,
                 '-merged',
                 '-poly', inShp,
                 '-split Plot',
                 '-odir', outDir,
                 '-olaz -v')
```

2

```
LASrun = LAStool('lascanopy', inDir,
                 '-keep_z 0.0 40.0',
                 '-drop_class 1',
                 '-files_are_plots',
                 '-names',
                 '-height_cutoff 0.5',   # for Pxx,Bxx, MAX, AVG, STD, SKE, KUR, QAV
                 '-cover_cutoff  1.3',   # for COV and DNS
                 '-max -avg -std -ske -kur -qav',
                 '-cov',  # canopy cover (%) first returns above the cover cutoff / all first retu
                 '-dns',  # (%) all returns above the cover cutoff   / all returns
                 '-b 25 50 75', # points in the lower 25% "voxel" / "points in the voxel" {voxel: column with height = maximum - cutoff}
                 '-c 0.5 1.3 10.0 20.0 35.0', # amount of points whose heights fall into the intervals
                 '-d 0.5 1.3 10.0 20.0 35.0', # (%) points with heights into the intervals / total
                 '-p 10 30 70 90',       # percentiles 10, 30, 70 and 90
                 '-odir', outDir,
                 '-o Atlas2016B_PlotMetrics.csv',
                 '-oasc -v')
```



Etapas do processo ALS com R e LAStools

Inferir e produzir mapas

Geração de métricas LiDAR para as parcelas disponíveis (página anterior):

file_name	max	avg	qav	std	ske	kur	p10	p30	p70	p90	b25	b50	b75	c00	c01	c02	c03	d00	d01	d02	d03	cov	dns
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot742.laz	29.23	17.96	372.84	7.1	-0.49	1.96	7.45	13.03	23.13	26.06	10.4	34.9	62.4	3	301	394	770	0.1	13.2	17.2	33.7	69.2	64.1
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot758.laz	31.4	23.82	591.49	4.92	-1.9	7.82	18.17	22.87	26.58	28.51	2	7.3	37.8	31	218	1002	8611	0.2	1.7	7.7	66.4	85.3	75.8
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot769.laz	31.28	22.44	538.82	5.96	-1.46	5.1	14.54	21.36	26.02	28.27	4.7	12.4	47.4	0	65	208	888	0	2.8	9	38.4	48.9	50.2
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot776.laz	23.09	18.56	355.19	3.28	-3.52	18.64	16.36	18.22	20.02	21	2.5	2.5	18.7	5	11	402	183	0.4	0.8	30.3	13.8	52.3	44.9
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot777.laz	24.64	18.57	370.7	5.1	-1.96	6.3	11.05	18.68	21.22	22.47	6.4	11	29.1	20	173	741	1212	0.4	3.5	15	24.6	47.6	43.1
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot778.laz	23.31	18.22	349.43	4.19	-2.51	9.71	15.02	18	20.3	21.47	4.7	6.3	24.4	7	51	602	396	0.2	1.7	20.4	13.4	40.7	35.6
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot779.laz	31.85	22.8	558.15	6.21	-1.75	5.86	15.01	21.81	26.46	28.29	6.1	10.9	45.7	31	491	806	5497	0.3	5.1	8.4	57.4	76.3	70.9
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot783.laz	24.81	17.83	345.95	5.28	-1.67	5.17	9.52	17.43	20.86	22.33	6.6	13.6	38.7	8	78	358	345	0.3	2.9	13.5	13	33.2	29.4
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot785.laz	22.49	16.32	282.8	4.06	-1.97	6.68	10.74	16.17	18.32	19.77	5.2	10.5	43.6	19	312	2851	263	0.4	6.1	55.3	5.1	76.5	66.5
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot793.laz	29.71	19.34	407.1	5.76	-0.93	3.62	11.52	17.38	22.79	25.8	6.2	19.9	65.8	2	90	486	667	0.1	4.6	24.6	33.7	74.2	62.8
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot798.laz	30.61	21.64	504.43	6.02	-1.61	5.34	12.68	21.09	25	27.16	6.3	11.9	47.6	13	161	385	1587	0.3	4.2	10	41.1	63.9	55.2
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot800.laz	23.36	18.03	339.22	3.76	-2.08	7.98	14.29	17.39	20.16	21.32	2.9	6.5	33.9	3	69	846	471	0.1	2	24.9	13.9	49.7	40.9
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot801.laz	26.76	20.67	449.46	4.7	-2.21	8.14	15.49	20.43	22.97	24.68	4	7.6	26.3	4	95	351	1382	0.1	2.5	9.2	36	53.9	47.7
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot825.laz	22.97	17.43	321.09	4.17	-1.75	6.26	12.6	16.61	20.08	21.1	3.3	8.2	36.5	2	39	383	190	0.1	1.4	13.8	6.9	24.5	22.1
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot827.laz	22.09	17.97	327.56	2.13	-1.16	7.28	15.55	16.97	19.28	20.39	0.1	0.3	24.8	0	5	1169	233	0	0.2	57	11.4	82.8	68.6
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot828.laz	24.09	19.27	378.26	2.6	-1.92	11.24	16.48	18.36	20.72	21.99	0.8	1.5	27.4	1	20	1300	992	0	0.6	39.8	30.3	83.5	70.7
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot830.laz	22.73	18.23	342.72	3.21	-3.1	15.11	16.32	17.65	19.7	20.89	2.4	4.2	21	32	217	5008	1639	0.3	2.3	52.6	17.2	82.6	72.2
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot831.laz	25.61	20.9	442.69	2.41	-3.25	22.53	19.01	20.27	21.97	23.3	0.6	1.4	14.1	1	21	558	1769	0	0.6	16.6	52.6	82.2	69.8
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot833.laz	33.5	26.12	720.95	6.21	-2.12	7.28	17.01	26.29	29.33	31.04	3.7	9.9	20.4	7	89	157	1682	0.2	2.8	5	53.5	73.4	61.3
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot839.laz	24.56	21.2	452.78	1.86	-4.07	39.62	19.41	20.5	22.06	23.08	0.4	0.4	2.8	0	8	330	1327	0	0.3	14	56.4	81.3	70.8
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot840.laz	31.46	25.07	644.24	3.98	-2.34	12.32	21.24	24.08	26.96	29.05	1	3.3	24.3	4	16	74	1441	0.1	0.5	2.5	47.8	59.8	50.8
C:/3D/ALS/PRJ_UPM3/CLOUDS/2016/ATLAS/B.plotsDrone/Plot841.laz	32.1	25.5	679.88	5.46	-2.36	8.82	20.33	25.39	28.4	29.67	3.1	7.5	21.2	4	115	197	2911	0.1	2.1	3.6	52.7	71.4	58.4

Etapas do processo ALS com R e LAStools

Inferir e produzir mapas

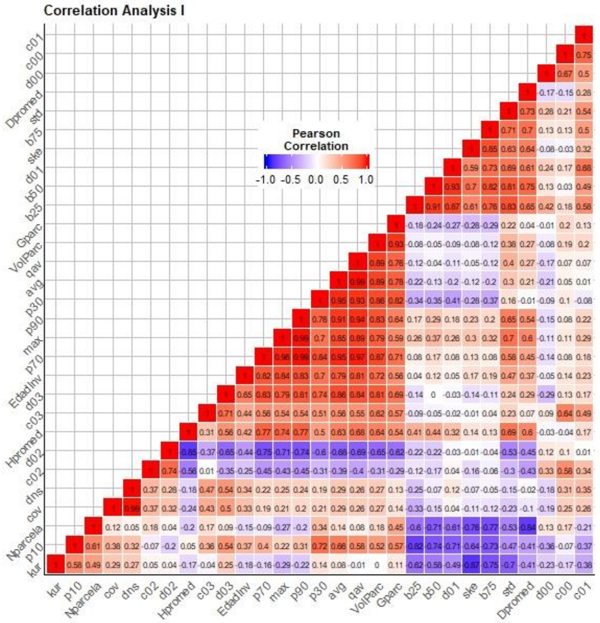
Correlacionar métricas e medições de campo disponíveis:

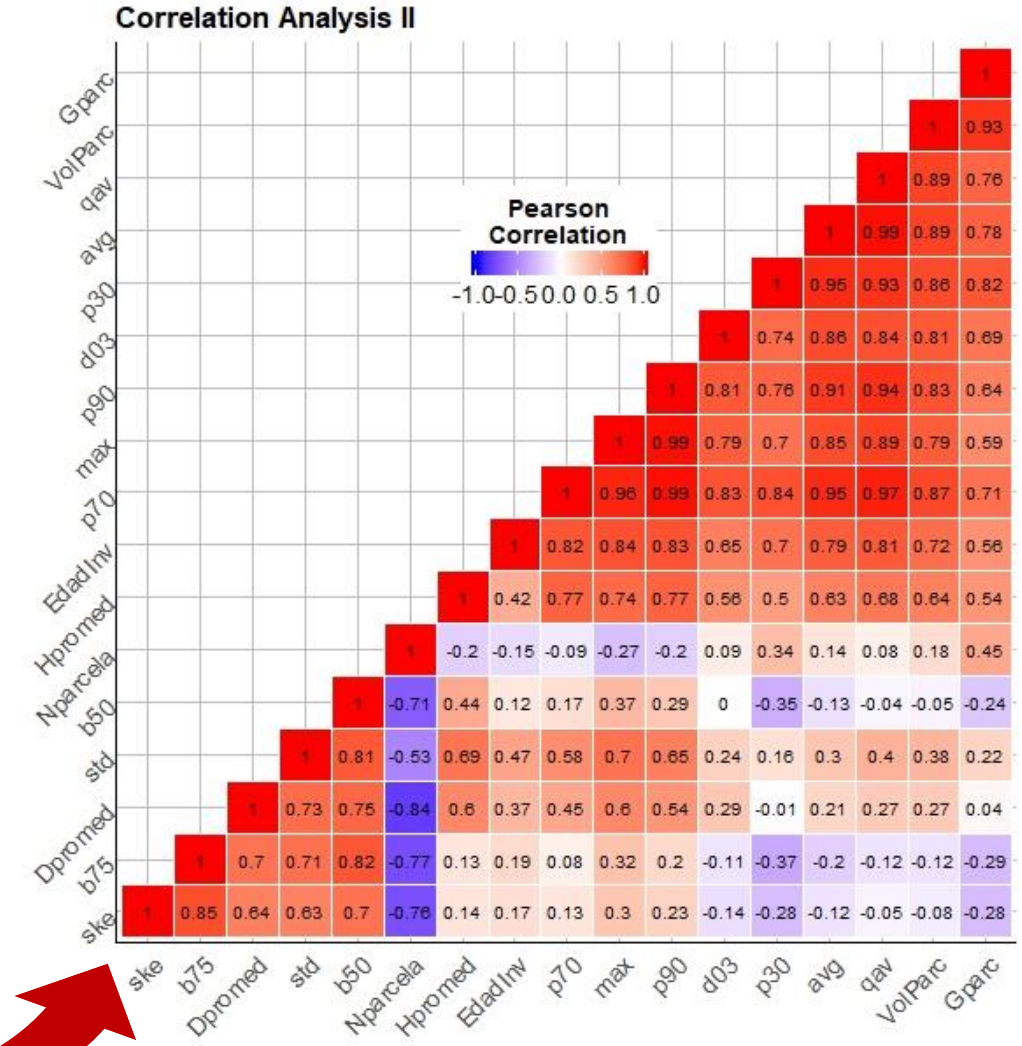
Year	Plot	Area_Parce	Cuadro	Ciclo	Rotacion	EdadInv	VolParc	Hpromed	Dpromed	Gparc	Nparcela	Vol_Ha	G_Ha	N_Ha
2017	Plot742	314.159265	Q004	1	2	9	5.926481	24.918182	24.722727	0.5931	11	148.162013	18.878959	350.140875
2017	Plot758	314.159265	Q243e	1	1	10	9.21805	22.711765	18.066176	1.022215	34	230.45125	32.538114	1082.253613
2017	Plot769	314.159265	Q002	1	2	10	7.486739	24.526316	22.994737	0.862467	19	187.168487	27.453177	604.788784
2017	Plot776	314.159265	L138a	2	1	9	6.078294	20.838095	15.72619	0.850238	42	151.957346	27.063916	1336.901522
2017	Plot777	314.159265	L138	2	1	9	6.996427	22.697297	17.248649	0.921093	37	174.910672	29.319301	1177.746579
2017	Plot778	314.159265	L138a	2	1	9	5.152684	20.618182	15.927273	0.703725	33	128.817109	22.400262	1050.422624
2017	Plot779	314.159265	L135	1	1	11	9.71079	22.677419	20.532258	1.152852	31	242.769757	36.696419	986.760647
2017	Plot783	314.159265	L137	2	1	8	6.285326	22.695652	20.445652	0.780389	23	157.133157	24.840553	732.112738
2017	Plot785	314.159265	L137a	1	2	9	5.497792	18.142857	16.305357	0.659613	28	137.444805	20.996134	891.267681
2017	Plot793	314.159265	L135	1	1	11	7.15954	19.842105	22.068421	0.823232	19	178.98851	26.204288	604.788784
2017	Plot798	314.159265	L173	2	1	10	8.115064	22.057895	22.263158	0.839578	19	202.876589	26.724598	604.788784
2017	Plot800	314.159265	L136	1	1	8	6.205506	20.295	15.7475	0.845087	40	155.137656	26.899955	1273.239545
2017	Plot801	314.159265	L165	2	1	9	9.314354	22.924324	19.140541	1.157487	37	232.858858	36.843956	1177.746579
2017	Plot825	314.159265	L134a	1	1	9	5.928427	20.946154	18.757692	0.756834	26	148.210679	24.090774	827.605704
2017	Plot827	314.159265	L150	1	2	9	5.599261	17.52	17.746	0.664683	25	139.981528	21.157517	795.774715
2017	Plot828	314.159265	L150	1	2	9	6.49908	18.860606	16.313636	0.778576	33	162.47699	24.782844	1050.422624
2017	Plot830	314.159265	L152	1	2	9	6.477614	19.044737	15.436842	0.799919	38	161.94036	25.462213	1209.577567
2017	Plot831	314.159265	L151	2	1	9	6.950582	19.965909	15.478409	0.887655	44	173.764562	28.254936	1400.563499
2017	Plot833	314.159265	L157	2	1	11	9.530566	23.925	17.608333	1.055508	36	238.264153	33.597863	1145.91559
2017	Plot839	314.159265	L151	2	1	9	7.796942	21.878788	18.543939	0.925697	33	194.923547	29.465851	1050.422624
2017	Plot840	314.159265	L156	2	1	11	8.655438	23.273333	18.545	0.950892	30	216.385939	30.267832	954.929659
2017	Plot841	314.159265	L156	2	1	11	11.540235	25.314286	20.072857	1.251743	35	288.505871	39.844217	1114.084602

Etapas do processo ALS com R e LAStools

Inferir e produzir mapas

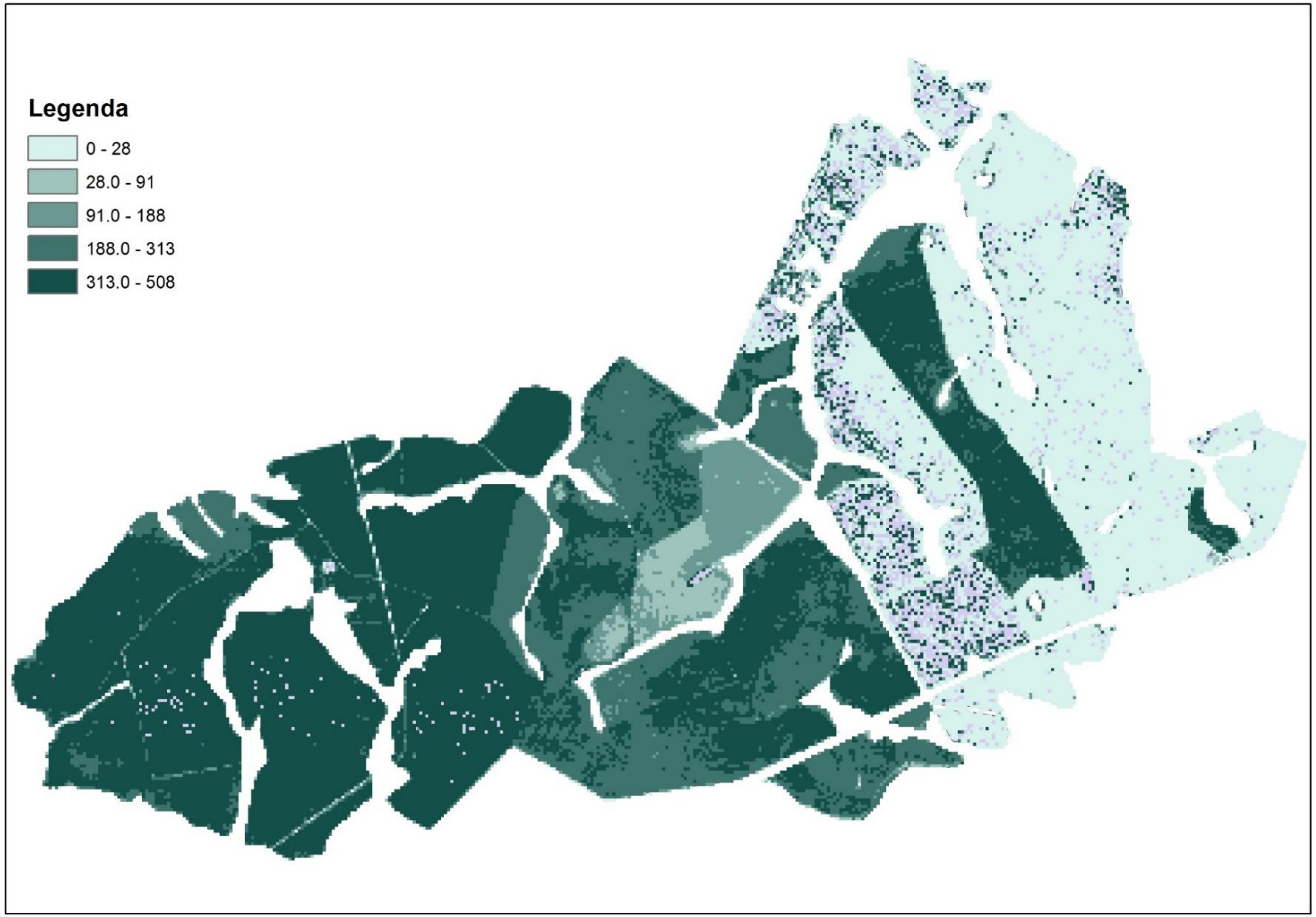
Buscando as melhores correlações



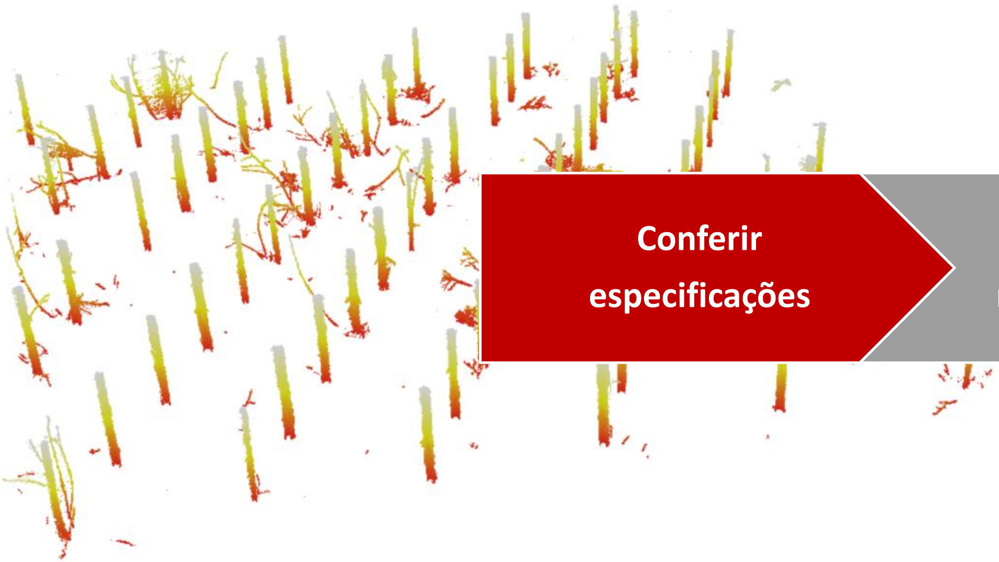


Etapas do processo ALS com R e LAStools

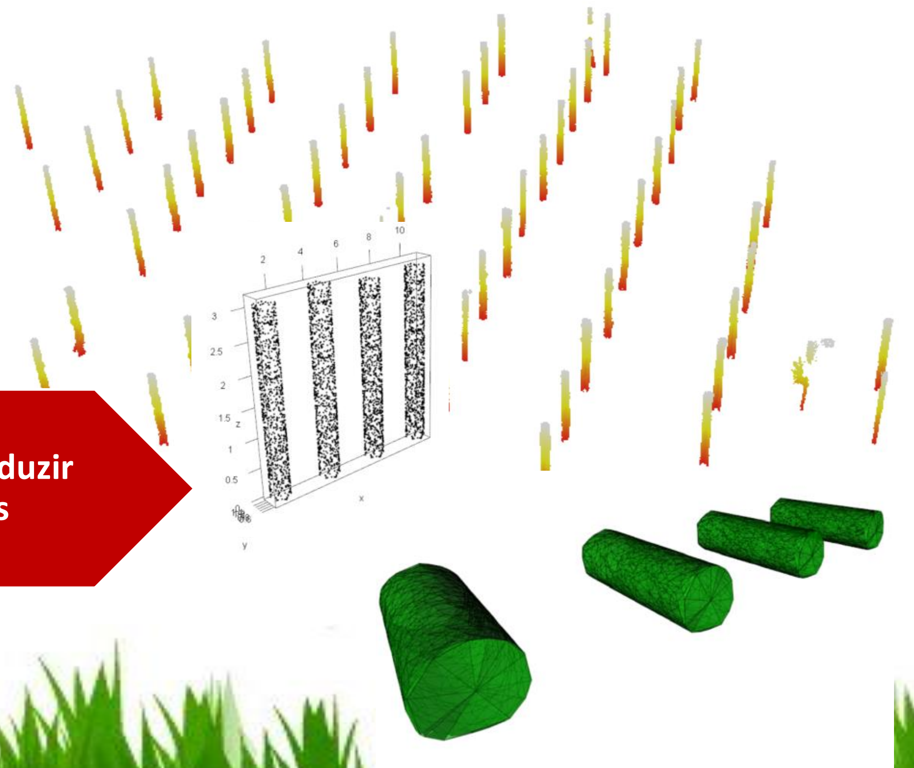
Inferir e produzir mapas



Etapas do processo TLS com R e LAStools



Conferir especificações → Arrumar nuvens -> LAZ → Classificar solo e determinar alturas dos pontos → Classificar pontos da vegetação → Classificar ruído …



… Criar nuvem para cada parcela → Normalizar parcelas → Isolar árvores, calcular volumes e métricas LiDAR → **Inferir e produzir modelos**

TreeLS

Algoritmos usados no programa **TLStrees**

- Algoritmo de duas etapas
  - *Pré-filtragem*
    - Remoção de ruído e isolamento prospectivo de troncos
  - *Ajuste fino*
    - Isolamento preciso de troncos por meio de ajuste de círculos/cilindros

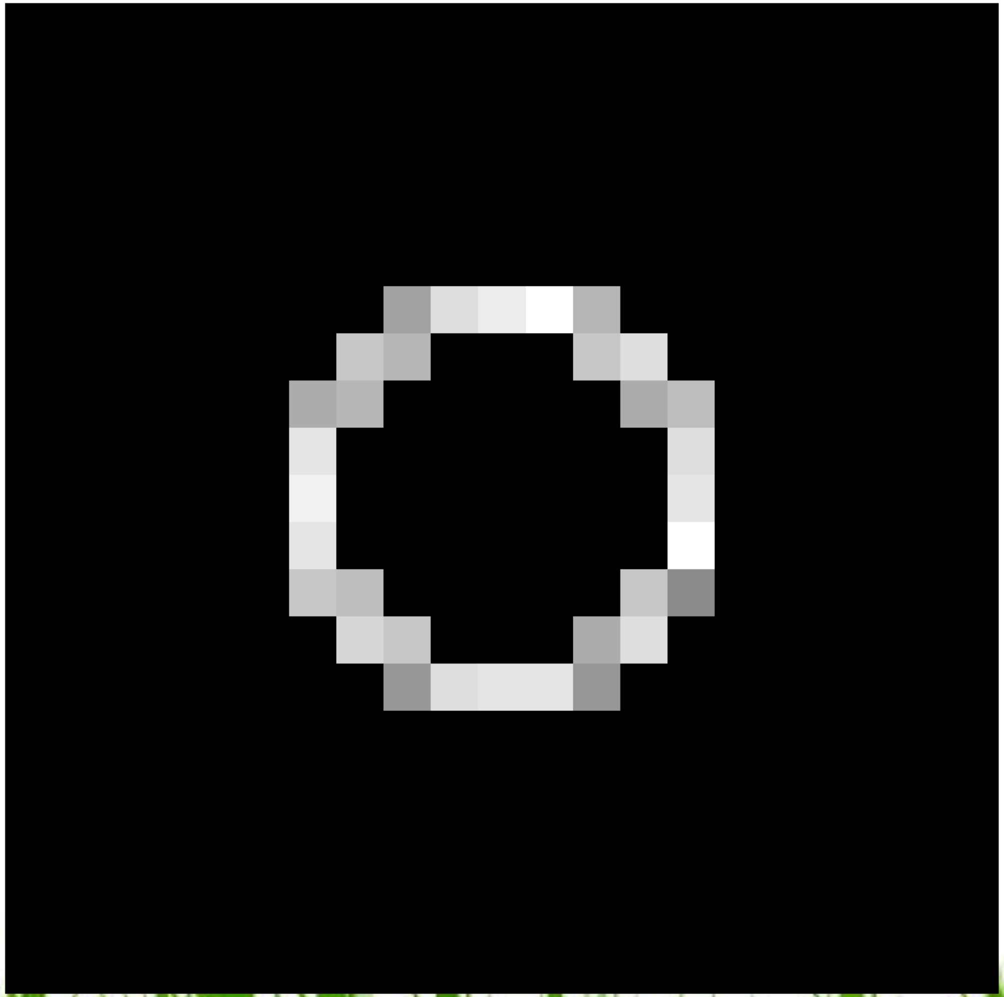
Algoritmos usados no programa TLStrees

Pré-filtragem

Hough transformation and RANSAC circle fit
adapted from Olofsson et. al. (2014)

Hough transformation

- adapted from Olofsson et. al. (2014)
- iterative method
- looks for specific 2D shapes on raster layers
- counts *votes* on each pixel



Algoritmos usados no programa TLStrees

Pré-filtragem

Etapas do processo TLS com R e LAStools

Ajuste fino

Hough transformation and **RANSAC circle fit**

adapted from Olofsson et. al. (2014)

- **RAN**dom **SA**mple **C**onsensus
- probability that all observations from a random sample belong to a model

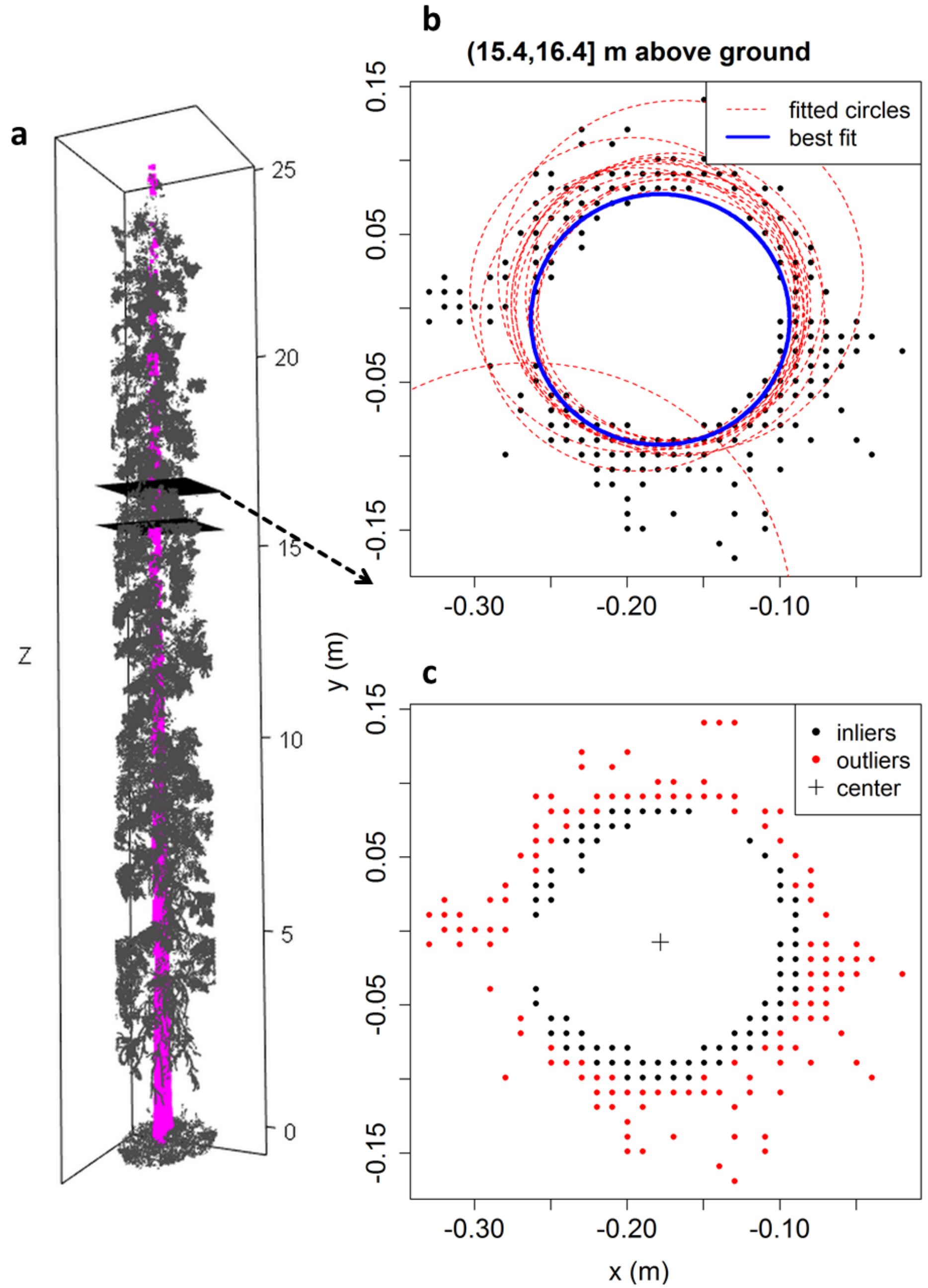
$$N = \frac{log(1-P)}{log(1-p^n)}$$

N = number of iterations

P = confidence level

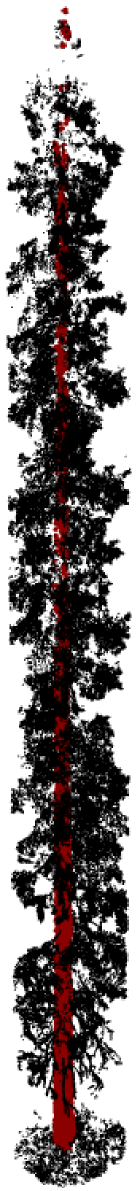
p = proportion of *inliers* in the dataset

n = size of random sample



Algoritmos usados no programa **TLStrees**

Ajuste fino



Segmentador de nuvens TLS

```
# /*** TLStrees ***/
# /*** Command line arguments ***/

# -i or --input        : input file path
# -o or --otxtdir      : output directory for the report files (defaults to current directory)
# -O or --olazdir      : output directory for the point cloud files (defaults to current directory)
# -l or --lower        : slice's lower height (default = 1.0 m)
# -u or --upper        : slice's upper height (default = 3.0 m)
# -z or --zheight      : height interval to search for stem segments (default = 0.5 m)
# -p or --pixel        : pixel size, in meters (default = 0.025 m)
# -r or --radius       : maximum radius to test (default = 0.25 m)
# -d or --density      : minimum density to consider on the Hough transform, from 0 to 1 (default = 0.1)
# -v or --votes        : minimum votes count at the output (default = 3 votes per pixel)
# -? or -h or --help   : print this help
```

Mais informação:

Tiago do Conto (2016) Dissertação de Mestrado
Performance of tree stem isolation algorithms for terrestrial laser scanning point clouds
https://stud.épsilon.slu.se/9502

Conto, Olofsson, Gorgens, Rodriguez & Almeida (2017)
Performance of stem denoising and stem modelling algorithms on single tree point clouds from terrestrial laser scanning Computers and Electronics in Agriculture v.143: 165-176
http://dx.doi.org/10.1016/j.compag.2017.10.019

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