Mapping pasture utilisation using R or using R as a GIS

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  - Livestock Industries Centre, NSW DPI
  - Chiswick, CSIRO

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Who am I?

- BAgSc (Adelaide); Grad Dip Stats (SAIT); MSci (Sydney); PhD (UNE)
- 1978-1981 DofA SA (Entomology & Plant Breeding)
- 1981-1984 DofA SA Dairy Scientist (Heifer growth & mammary development)
- 1984-1990 DofA Tas Dairy Scientist – cow nutrition, heifer growth, pasture management, DST development
- 1990-present NSW DPI Scientist – DST/mathematical modelling; dairy heifer growth (Camden); Precision Livestock Management (UNE PARG since 2009)
- Adjunct with S&T
- Started using R in ~2007 (previously GLIM/Minitab/SPSS/SAS/Genstat)
    - Statistical analysis, experimental design, modelling, spatial analysis, machine learning

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About this talk

- Livestock Productivity Partnership (LPP)
- Why measure pasture utilisation?
- Problem definition
- Steps to building shapefiles/polygons
    - Lots of R script
- Pasture data collection – using CDAX pasture meter
- Steps to creating maps (geostatistics)
    - Lots of R script
- Maps
- Animation

What is LPP?

- Collaboration between NSW DPI, CSIRO, UNE and MLA Donor Company (MDC)
- ~$50m
- 3 programs
  - Pastures
  - Livestock
  - Information systems

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Why measure pasture utilisation?

- Pasture yield is the result of many factors
  - Species, soils, rainfall, temperature, grazing management, fertility, irrigation etc
- Variability
  - Some areas high yielding, others low
- Cost-effective targeted management
  - Eg fertiliser application, grazing allocation
- Opportunities now exist to develop strategic approaches for extensive livestock industries
- Major driver of enterprise profitability

Problem definition

- Where in the paddock do livestock graze?
- How long do livestock stay in that part of the paddock?
- How much do they eat?
- What effect does this have on pasture composition?
- What effect does this have on pasture and animal productivity?

Improving profit from pasture through increased feed efficiency

- Identify efficient grazers (cattle)
- CSIRO Chiswick – Big Ridge
  - Annual ryegrass and natural
- 10 "plots" (5 ha) – divided into 40 smaller plots (25mx50m)
  - + WoW paddock (11 ha) – not in this talk
- Measurements
  - Pasture (focus of this talk)
  - Animal + GPS+IMU (not in this talk)

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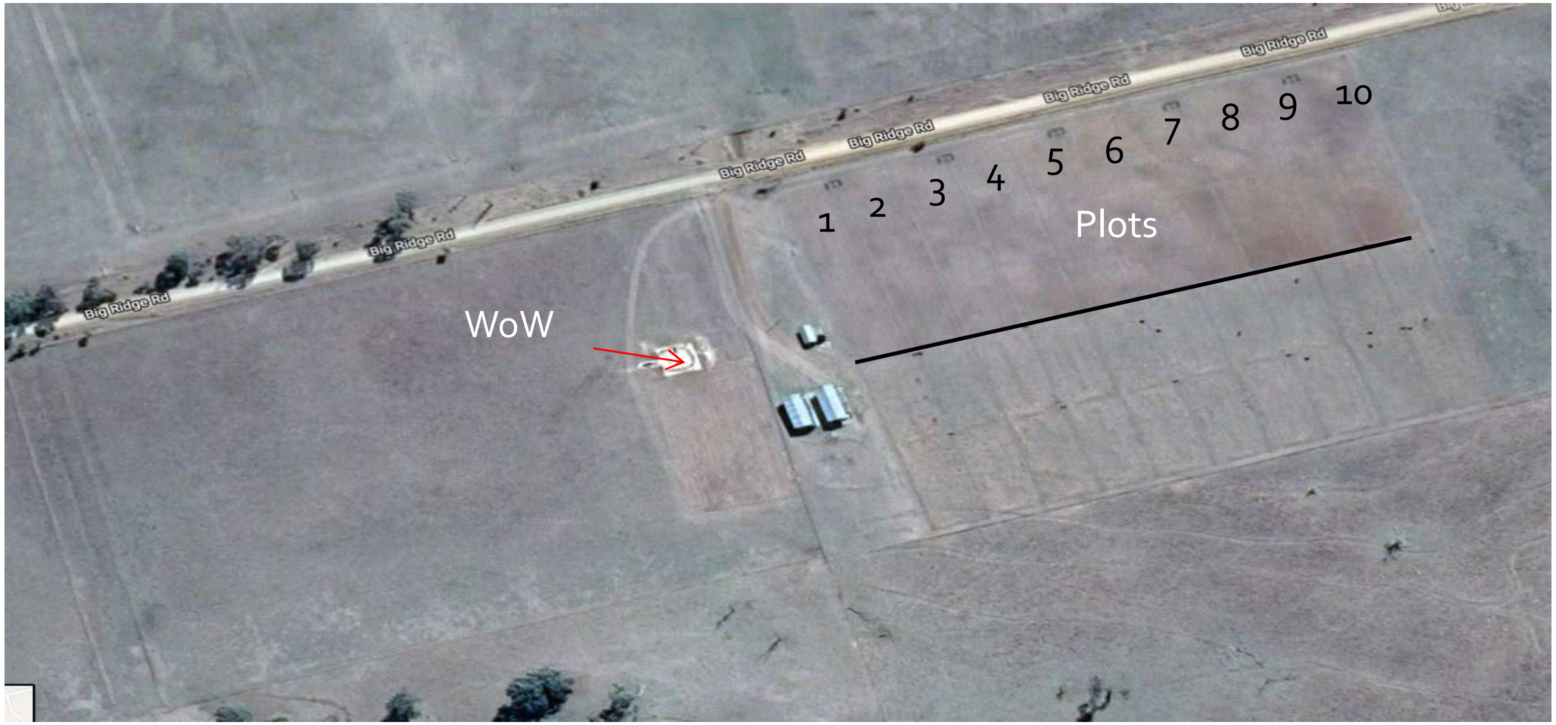
Big Ridge experimental plots



From Google maps

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Pasture utilisation map making

A number of steps:

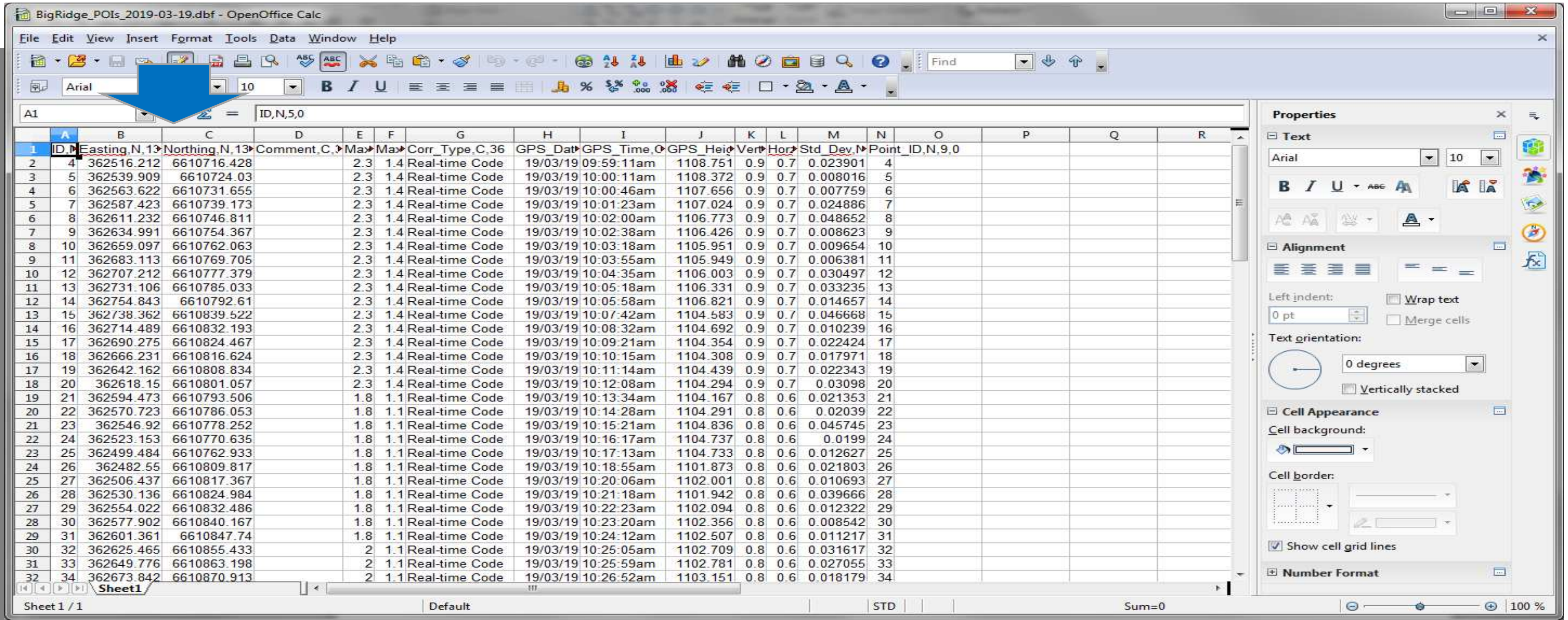
1. Map paddock using dGPS
   - create shapefiles
2. Collect pasture height data
3. Load data and shapefile
4. Add CDAX GPS points (mobile pasture meter)
5. Create grid
6. Fit variogram (geostatistics)
7. Create maps
8. Plot the maps

Step 1. Map paddock

dGPS

File types created:
.shp; .dbf; .prj; .shx; .sbx; .sbn
ESRI format

Step 1. Map paddock



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	ID,N	Easting,N,13	Northing,N,13	Comment,C,	Max	Max	Corr_Type,C,36	GPS_Dat	GPS_Time,C	GPS_Heig	Vert	Horz	Std_Dev,N	Point_ID,N,9,0
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3	5	362539.909	6610724.03		2.3	1.4	Real-time Code	19/03/19	10:00:11am	1108.372	0.9	0.7	0.008016	5
4	6	362563.622	6610731.655		2.3	1.4	Real-time Code	19/03/19	10:00:46am	1107.656	0.9	0.7	0.007759	6
5	7	362587.423	6610739.173		2.3	1.4	Real-time Code	19/03/19	10:01:23am	1107.024	0.9	0.7	0.024886	7
6	8	362611.232	6610746.811		2.3	1.4	Real-time Code	19/03/19	10:02:00am	1106.773	0.9	0.7	0.048652	8
7	9	362634.991	6610754.367		2.3	1.4	Real-time Code	19/03/19	10:02:38am	1106.426	0.9	0.7	0.008623	9
8	10	362659.097	6610762.063		2.3	1.4	Real-time Code	19/03/19	10:03:18am	1105.951	0.9	0.7	0.009654	10
9	11	362683.113	6610769.705		2.3	1.4	Real-time Code	19/03/19	10:03:55am	1105.949	0.9	0.7	0.006381	11
10	12	362707.212	6610777.379		2.3	1.4	Real-time Code	19/03/19	10:04:35am	1106.003	0.9	0.7	0.030497	12
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13	15	362738.362	6610839.522		2.3	1.4	Real-time Code	19/03/19	10:07:42am	1104.583	0.9	0.7	0.046668	15
14	16	362714.489	6610832.193		2.3	1.4	Real-time Code	19/03/19	10:08:32am	1104.692	0.9	0.7	0.010239	16
15	17	362690.275	6610824.467		2.3	1.4	Real-time Code	19/03/19	10:09:21am	1104.354	0.9	0.7	0.022424	17
16	18	362666.231	6610816.624		2.3	1.4	Real-time Code	19/03/19	10:10:15am	1104.308	0.9	0.7	0.017971	18
17	19	362642.162	6610808.834		2.3	1.4	Real-time Code	19/03/19	10:11:14am	1104.439	0.9	0.7	0.022343	19
18	20	362618.15	6610801.057		2.3	1.4	Real-time Code	19/03/19	10:12:08am	1104.294	0.9	0.7	0.03098	20
19	21	362594.473	6610793.506		1.8	1.1	Real-time Code	19/03/19	10:13:34am	1104.167	0.8	0.6	0.021353	21
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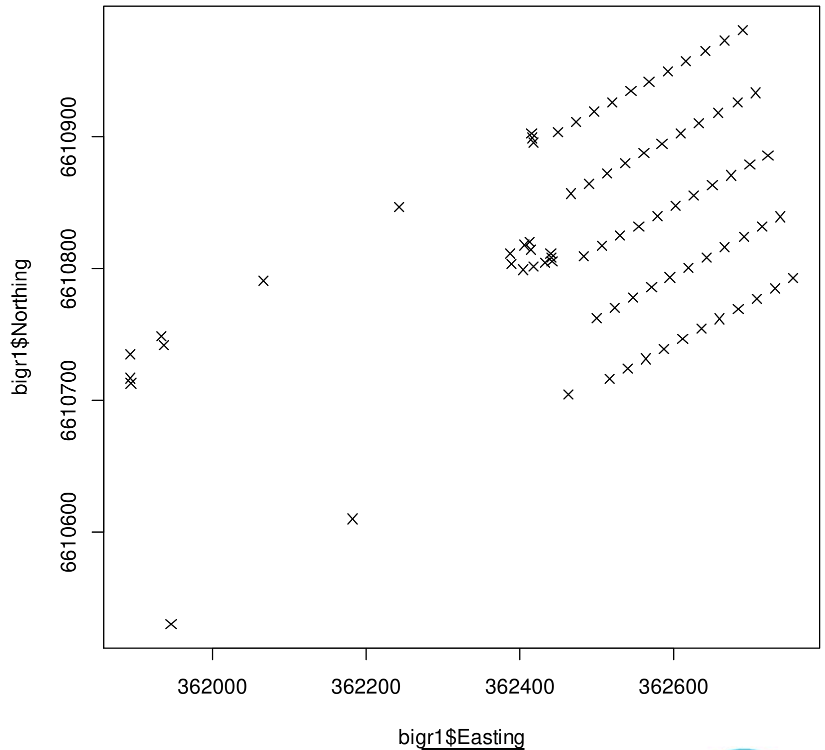
21	23	362546.92	6610778.252		1.8	1.1	Real-time Code	19/03/19	10:15:21am	1104.836	0.8	0.6	0.045745	23
22	24	362523.153	6610770.635		1.8	1.1	Real-time Code	19/03/19	10:16:17am	1104.737	0.8	0.6	0.0199	24
23	25	362499.484	6610762.933		1.8	1.1	Real-time Code	19/03/19	10:17:13am	1104.733	0.8	0.6	0.012627	25
24	26	362482.55	6610809.817		1.8	1.1	Real-time Code	19/03/19	10:18:55am	1101.873	0.8	0.6	0.021803	26
25	27	362506.437	6610817.367		1.8	1.1	Real-time Code	19/03/19	10:20:06am	1102.001	0.8	0.6	0.010693	27
26	28	362530.136	6610824.984		1.8	1.1	Real-time Code	19/03/19	10:21:18am	1101.942	0.8	0.6	0.039666	28
27	29	362554.022	6610832.486		1.8	1.1	Real-time Code	19/03/19	10:22:23am	1102.094	0.8	0.6	0.012322	29
28	30	362577.902	6610840.167		1.8	1.1	Real-time Code	19/03/19	10:23:20am	1102.356	0.8	0.6	0.008542	30
29	31	362601.361	6610847.74		1.8	1.1	Real-time Code	19/03/19	10:24:12am	1102.507	0.8	0.6	0.011217	31
30	32	362625.465	6610855.433		2	1.1	Real-time Code	19/03/19	10:25:05am	1102.709	0.8	0.6	0.031617	32
31	33	362649.776	6610863.198		2	1.1	Real-time Code	19/03/19	10:25:59am	1102.781	0.8	0.6	0.027055	33
32	34	362673.842	6610870.913		2	1.1	Real-time Code	19/03/19	10:26:52am	1103.151	0.8	0.6	0.018179	34

Step 1. Map paddock - Point data from dGPS



R libraries
rgdal (Bindings for the 'Geospatial' Data Abstraction Library)
sp (Classes and Methods for Spatial Data)

```
bigr<-readOGR(dsn=locate_file,
layer="BigRidge_POIs_2019-03-19")
bigr1<-data.frame(bigr) # make data frame

plot(bigr1$Easting, bigr1$Northing,pch=4)
```

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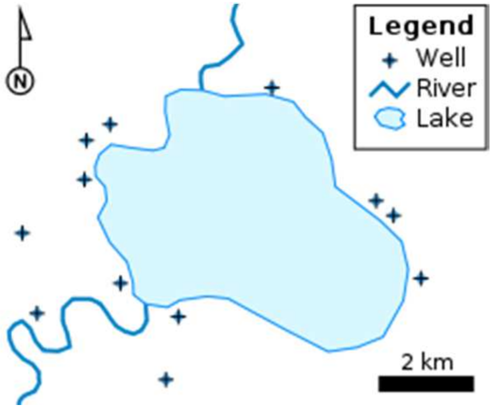
Step 1. Create shapefiles

What is a shapefile?

The shapefile format is a popular geospatial vector data format for geographic information system software. It is developed and regulated by Esri as a open specification for data interoperability among Esri and other GIS software products. (Wikipedia 11/5/2019)



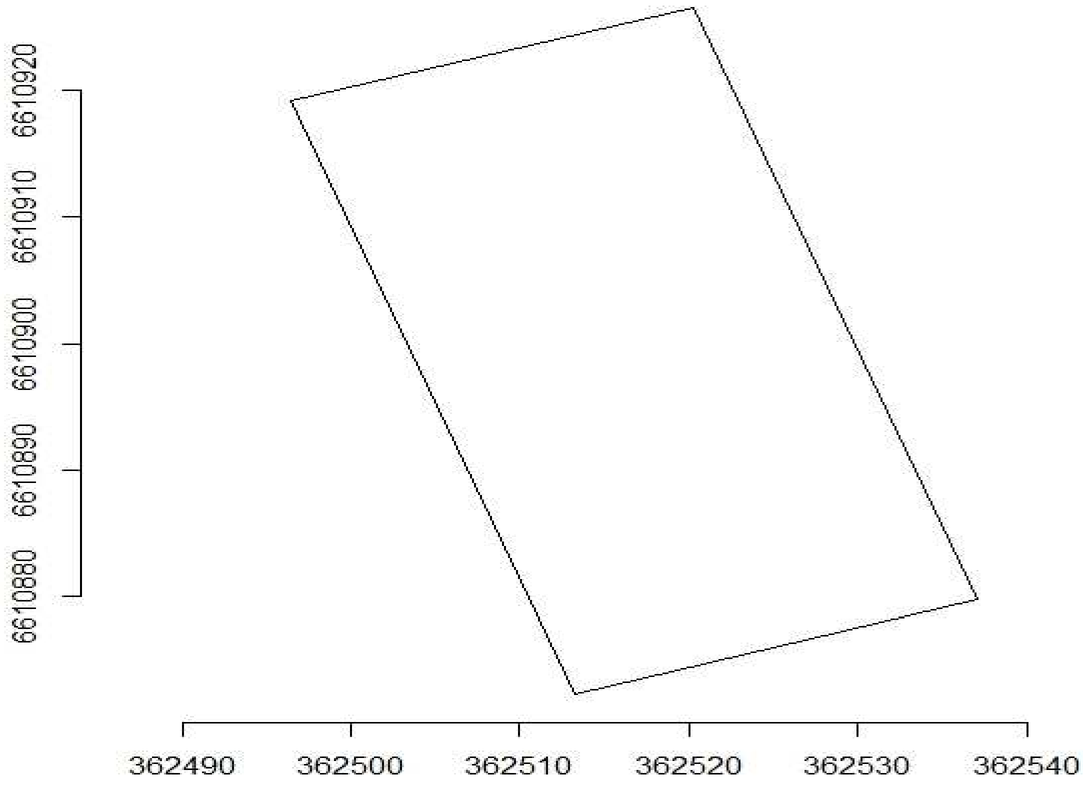
https://www.gislounge.com/what-is-a-shapefile/

Step 1. Create paddock shapefiles in R

```
LR3_1<-c(bigr1[41,2],bigr1[41,3]) # coordinates for lower ryegrass plot 3
LR3_2<-c(bigr1[42,2],bigr1[42,3])
LR3_3<-c(bigr1[47,2],bigr1[47,3])
LR3_4<-c(bigr1[48,2],bigr1[48,3])
## create polygon and save to file
bigr1_LR3<-rbind(LR3_1,LR3_2,LR3_3,LR3_4)
xLR3 <- bigr1_LR3[,1]
yLR3 <- bigr1_LR3[,2]
xyLR3 <- cbind(xLR3, yLR3)
pLR3 = Polygon(xyLR3)
psLR3 = Polygons(list(pLR3),1)
spsLR3 = SpatialPolygons(list(psLR3))
proj4string(spsLR3) = CRS("+init=epsg:32756")
dLR3 = data.frame(f=1) # only one field
spdfLR3 = SpatialPolygonsDataFrame(spsLR3,dLR3)
writeOGR(spdfLR3, dsn=locate_file, layer="LR3_BigR", driver="ESRI Shapefile")
```

Step 1. LR3 shapefile

```
plot(LR3)
axis(1)
axis(2)
```



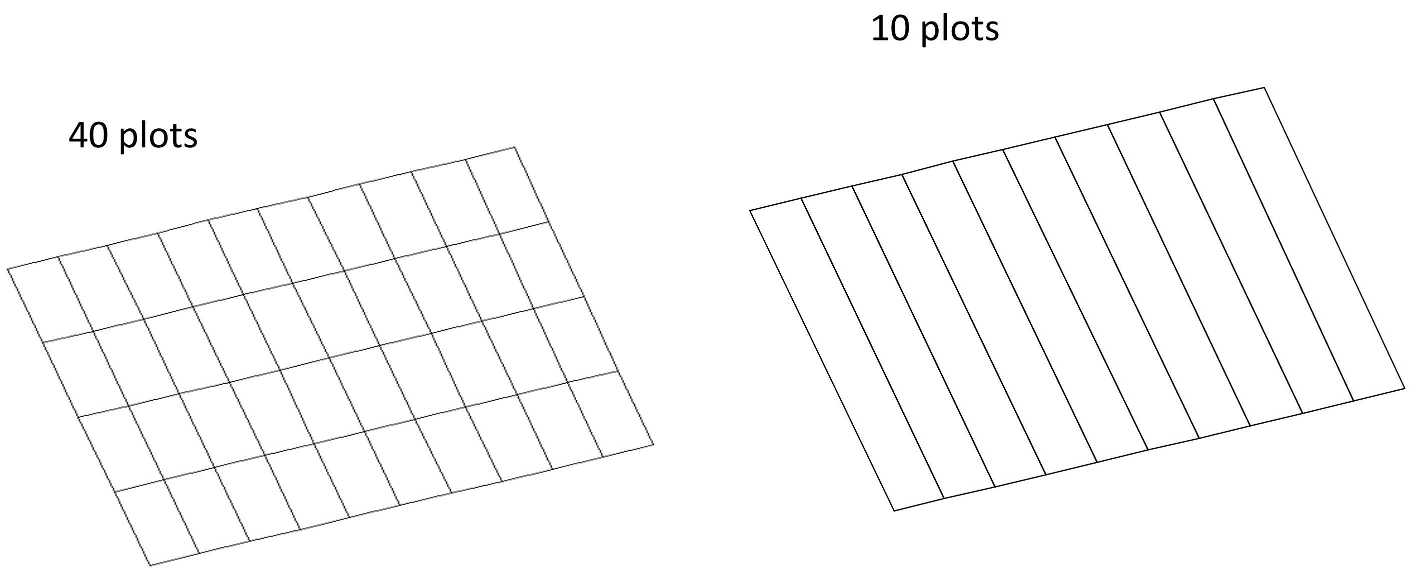
Step 1. Create shapefiles – combine plots

```
library(maptools); library(sp); library(rgdal)

# plot 1
## select relevant coordinates
P101_1<-c(bigr1[1,2],bigr1[1,3]) # coordinates
P101_2<-c(bigr1[2,2],bigr1[2,3])
P101_3<-c(bigr1[46,2],bigr1[46,3])
P101_4<-c(bigr1[45,2],bigr1[45,3])
## create polygon and save to file
bigr1_P101<-rbind(P101_1,P101_2,P101_3,P101_4)
xP101 <- bigr1_P101[,1]
yP101 <- bigr1_P101[,2]
xyP101 <- cbind(xP101, yP101)
pP101 = Polygon(xyP101)
```

Step 1. Create shapefiles – combine plots

```
TenPolys <- sp::SpatialPolygons(list(sp::Polygons(list(pP101),ID = "P1"),
                                     sp::Polygons(list(pP102), ID = "P2"),
                                     sp::Polygons(list(pP103), ID = "P3"),
                                     sp::Polygons(list(pP104), ID = "P4"),
                                     sp::Polygons(list(pP105), ID = "P5"),
                                     sp::Polygons(list(pP106), ID = "P6"),
                                     sp::Polygons(list(pP107), ID = "P7"),
                                     sp::Polygons(list(pP108), ID = "P8"),
                                     sp::Polygons(list(pP109), ID = "P9"),
                                     sp::Polygons(list(pP110), ID = "P10")))

shapefile(x = TenPolys, file = "N:/CDAX/Linker CDAX/Shapefiles/Ten.shp")
```

Step 1. Create shapefiles – combine shapefiles



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Step 2. Pasture measurement - CDAX points

CDAX – height/laser @ 200Hz + GPS

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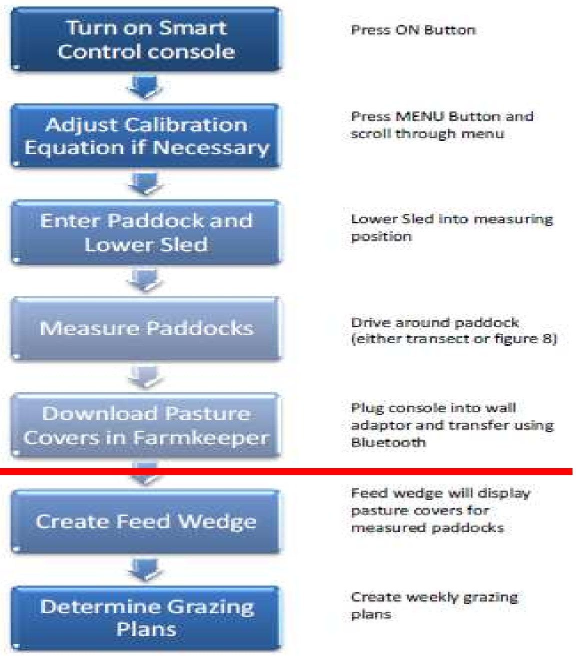
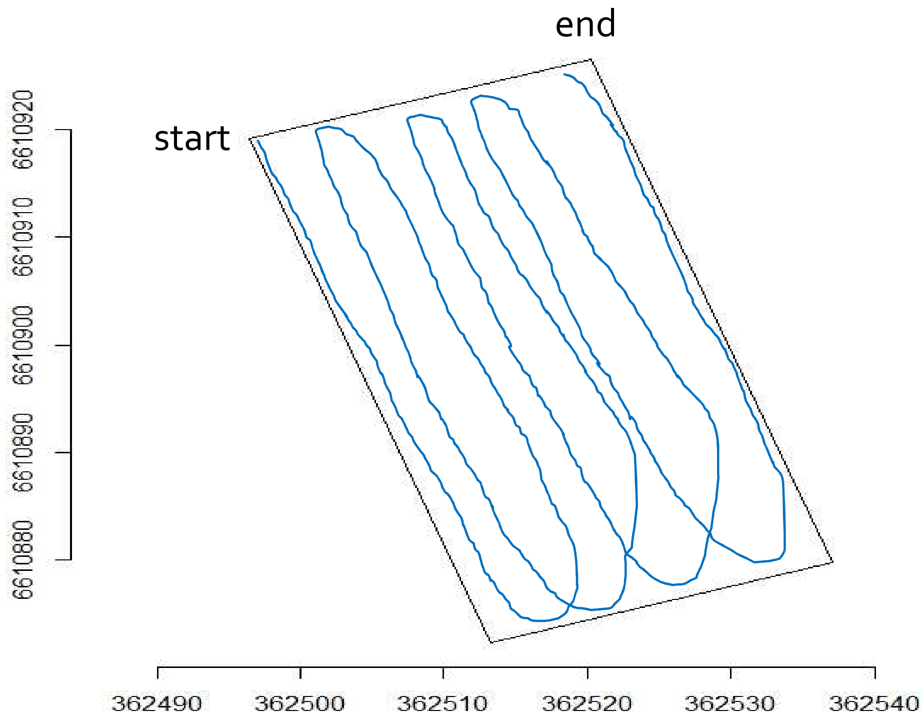
How the measurement process works

The steps below outline the overall process for obtaining and recording your farm's pasture cover. They will be explained in the remaining sections of this guide.



Step 2. CDAX track within plot/paddock



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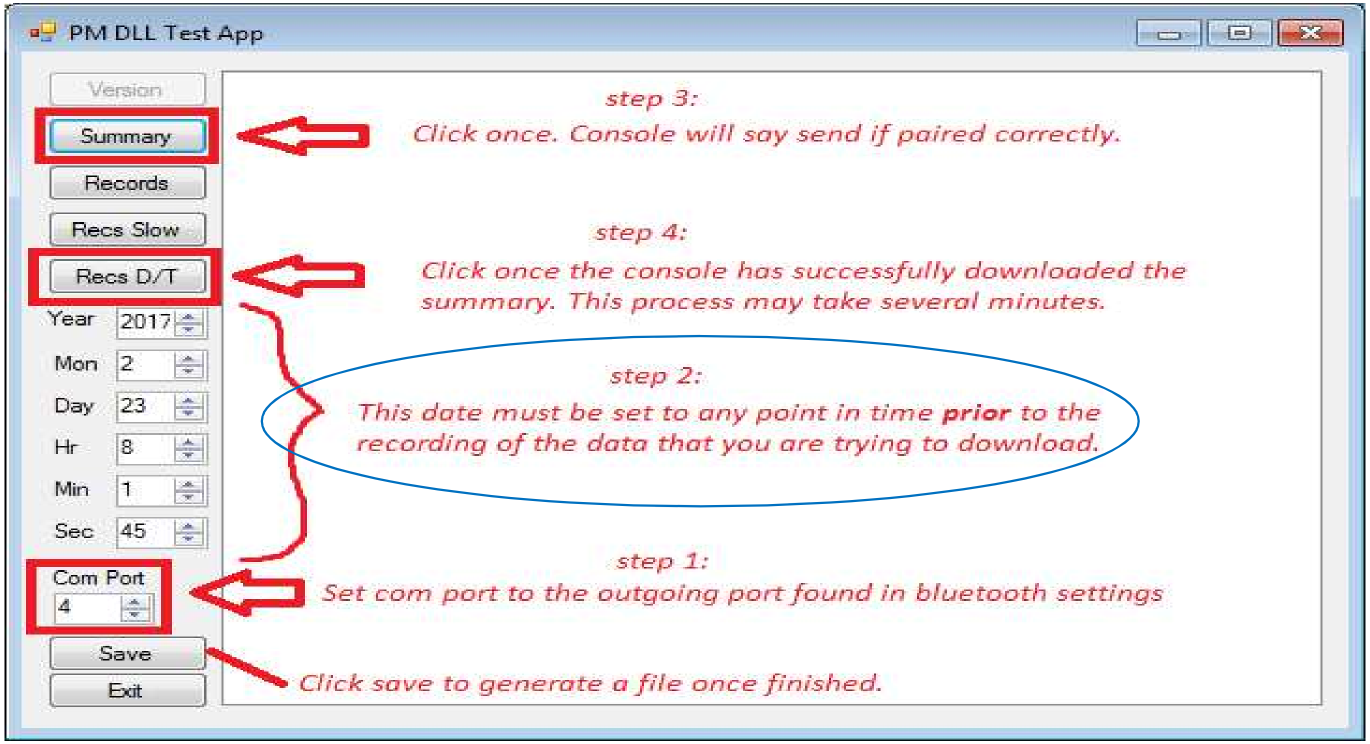
Step 2. CDAX data download instructions via Bluetooth



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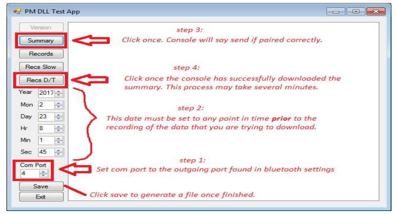
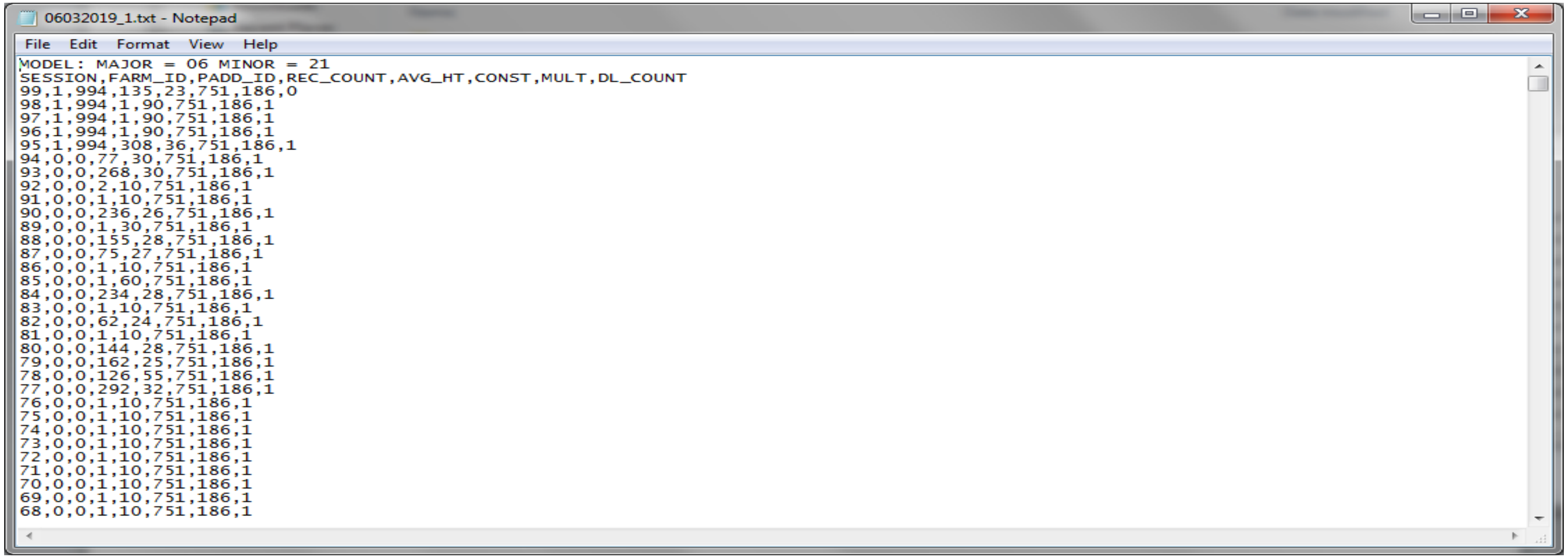
Step 2. CDAX data



Summary data – 99 sessions (Step 3 of download instructions)



06032019_1.txt - Notepad

File Edit Format View Help

```
MODEL: MAJOR = 06 MINOR = 21
SESSION,FARM_ID,PADD_ID,REC_COUNT,AVG_HT,CONST,MULT,DL_COUNT
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98,1,994,1,90,751,186,1
97,1,994,1,90,751,186,1
96,1,994,1,90,751,186,1
95,1,994,308,36,751,186,1
94,0,0,77,30,751,186,1
93,0,0,268,30,751,186,1
92,0,0,2,10,751,186,1
91,0,0,1,10,751,186,1
90,0,0,236,26,751,186,1
89,0,0,1,30,751,186,1
88,0,0,155,28,751,186,1
87,0,0,75,27,751,186,1
86,0,0,1,10,751,186,1
85,0,0,1,60,751,186,1
84,0,0,234,28,751,186,1
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82,0,0,62,24,751,186,1
81,0,0,1,10,751,186,1
80,0,0,144,28,751,186,1
79,0,0,162,25,751,186,1
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77,0,0,292,32,751,186,1
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72,0,0,1,10,751,186,1
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70,0,0,1,10,751,186,1
69,0,0,1,10,751,186,1
68,0,0,1,10,751,186,1
```
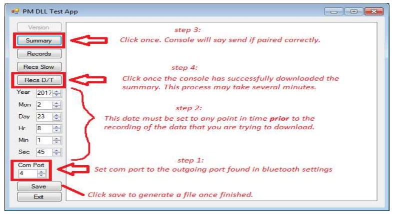
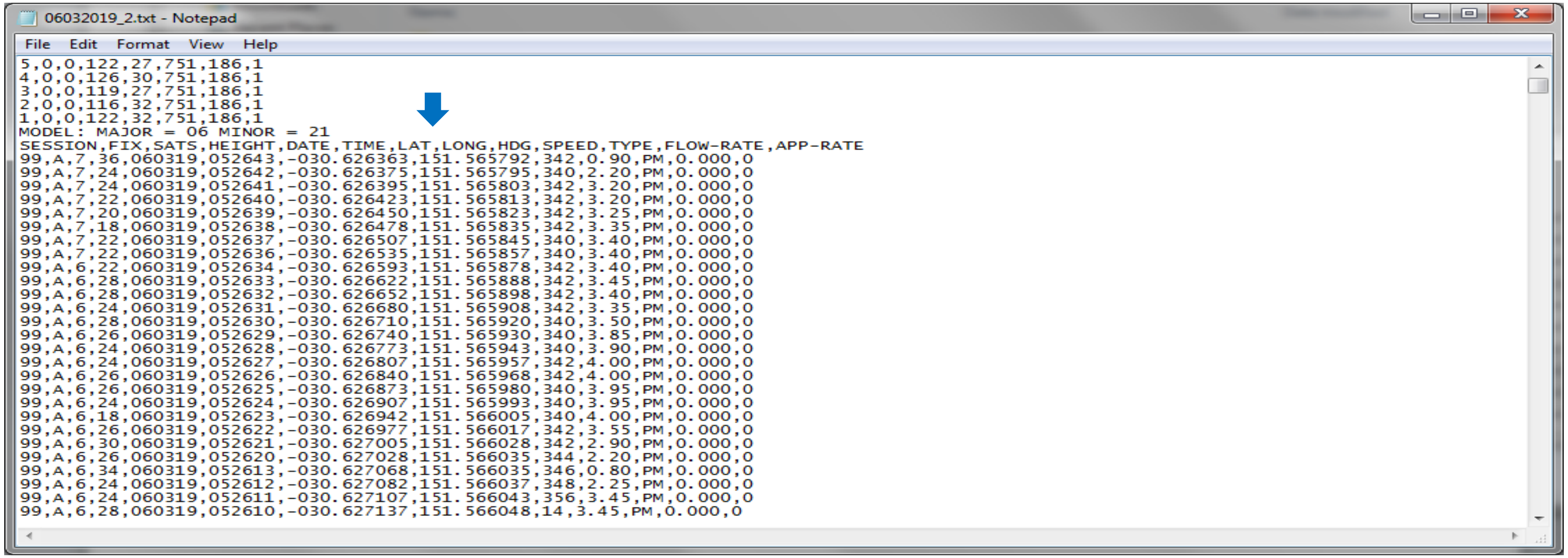

Step 3. CDAX data – GPS locations



Data for each "session" or "run" + GPS locations
(Step 4 of download instructions)


06032019_2.txt - Notepad

File Edit Format View Help

```
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3,0,0,119,27,751,186,1
2,0,0,116,32,751,186,1
1,0,0,122,32,751,186,1
MODEL: MAJOR = 06 MINOR = 21
SESSION,FIX,SATS,HEIGHT,DATE,TIME,LAT,LONG,HDG,SPEED,TYPE,FLOW-RATE,APP-RATE
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99,A,7,24,060319,052641,-030.626395,151.565803,342,3.20,PM,0.000,0
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99,A,7,20,060319,052639,-030.626450,151.565823,342,3.25,PM,0.000,0
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99,A,7,22,060319,052637,-030.626507,151.565845,340,3.40,PM,0.000,0
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99,A,6,18,060319,052623,-030.626942,151.566005,340,4.00,PM,0.000,0
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99,A,6,28,060319,052610,-030.627137,151.566048,14,3.45,PM,0.000,0
```
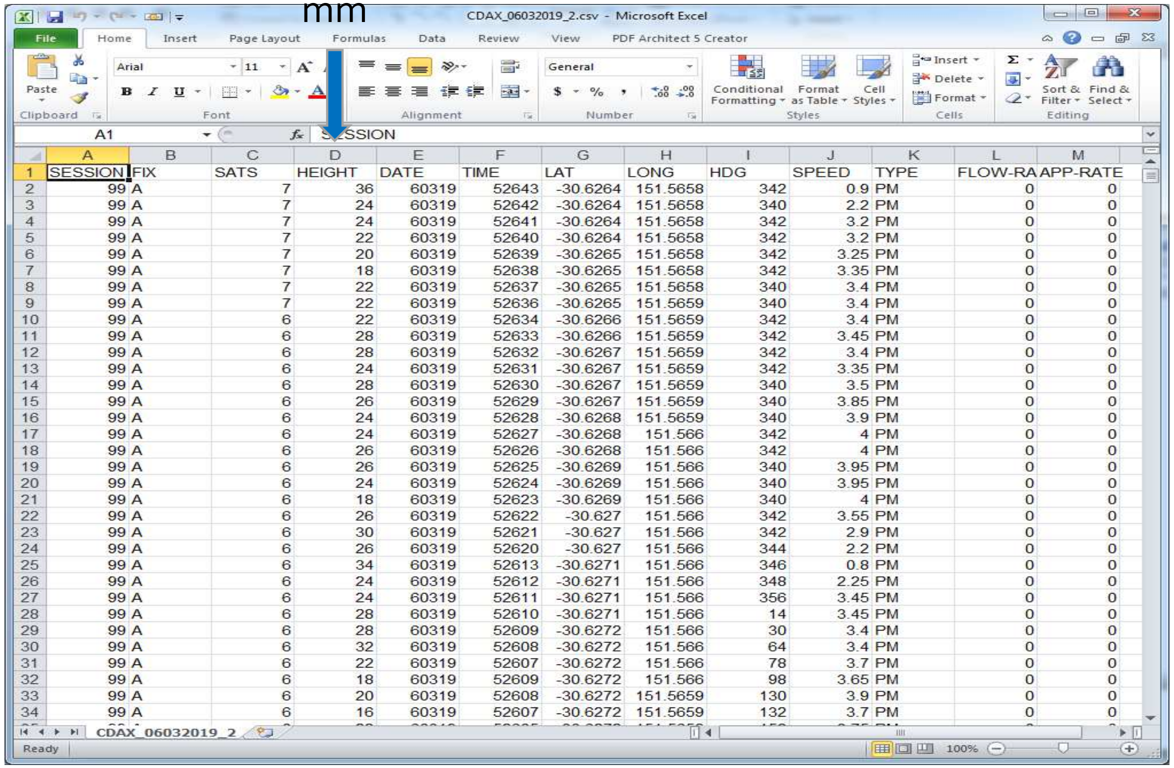

Step 2. Create csv file for analysis

mm

CDAX92.csv



	SESSION	FIX	SATS	HEIGHT	DATE	TIME	LAT	LONG	HDG	SPEED	TYPE	FLOW-RA	APP-RATE
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3	99	A	7	24	60319	52642	-30.6264	151.5658	340	2.2	PM	0	0
4	99	A	7	24	60319	52641	-30.6264	151.5658	342	3.2	PM	0	0
5	99	A	7	22	60319	52640	-30.6264	151.5658	342	3.2	PM	0	0
6	99	A	7	20	60319	52639	-30.6265	151.5658	342	3.25	PM	0	0
7	99	A	7	18	60319	52638	-30.6265	151.5658	342	3.35	PM	0	0
8	99	A	7	22	60319	52637	-30.6265	151.5658	340	3.4	PM	0	0
9	99	A	7	22	60319	52636	-30.6265	151.5659	340	3.4	PM	0	0
10	99	A	6	22	60319	52634	-30.6266	151.5659	342	3.4	PM	0	0
11	99	A	6	28	60319	52633	-30.6266	151.5659	342	3.45	PM	0	0
12	99	A	6	28	60319	52632	-30.6267	151.5659	342	3.4	PM	0	0
13	99	A	6	24	60319	52631	-30.6267	151.5659	342	3.35	PM	0	0
14	99	A	6	28	60319	52630	-30.6267	151.5659	340	3.5	PM	0	0
15	99	A	6	26	60319	52629	-30.6267	151.5659	340	3.85	PM	0	0
16	99	A	6	24	60319	52628	-30.6268	151.5659	340	3.9	PM	0	0
17	99	A	6	24	60319	52627	-30.6268	151.566	342	4	PM	0	0
18	99	A	6	26	60319	52626	-30.6268	151.566	342	4	PM	0	0
19	99	A	6	26	60319	52625	-30.6269	151.566	340	3.95	PM	0	0
20	99	A	6	24	60319	52624	-30.6269	151.566	340	3.95	PM	0	0
21	99	A	6	18	60319	52623	-30.6269	151.566	340	4	PM	0	0
22	99	A	6	26	60319	52622	-30.627	151.566	342	3.55	PM	0	0
23	99	A	6	30	60319	52621	-30.627	151.566	342	2.9	PM	0	0
24	99	A	6	26	60319	52620	-30.627	151.566	344	2.2	PM	0	0
25	99	A	6	34	60319	52613	-30.6271	151.566	346	0.8	PM	0	0
26	99	A	6	24	60319	52612	-30.6271	151.566	348	2.25	PM	0	0
27	99	A	6	24	60319	52611	-30.6271	151.566	356	3.45	PM	0	0
28	99	A	6	28	60319	52610	-30.6271	151.566	14	3.45	PM	0	0
29	99	A	6	28	60319	52609	-30.6272	151.566	30	3.4	PM	0	0
30	99	A	6	32	60319	52608	-30.6272	151.566	64	3.4	PM	0	0
31	99	A	6	22	60319	52607	-30.6272	151.566	78	3.7	PM	0	0
32	99	A	6	18	60319	52609	-30.6272	151.566	98	3.65	PM	0	0
33	99	A	6	20	60319	52608	-30.6272	151.5659	130	3.9	PM	0	0
34	99	A	6	16	60319	52607	-30.6272	151.5659	132	3.7	PM	0	0

Simulation – pasture height change over time (0-12 days)

Day 0 – as measured

Day 4 – if height > 70 then * 0.4, if 40< height <=70 then * 0.2, if height <= 40 * 1.0

Day 8 - if height > =40 then * 0.4, if 20<= height < 40 then * 0.25, if height < 20 * 0.2

Day 12 -if height >= 30 then * 0.4, if 20<= height < 30 then * 0.2, if height < 20 * 0.1

HEIGHT	Height4	Height8	Height12
50	40	24	19.2
76	45.6	27.36	21.888
76	45.6	27.36	21.888
68	54.4	32.64	26.112
52	41.6	24.96	19.968

N= 264

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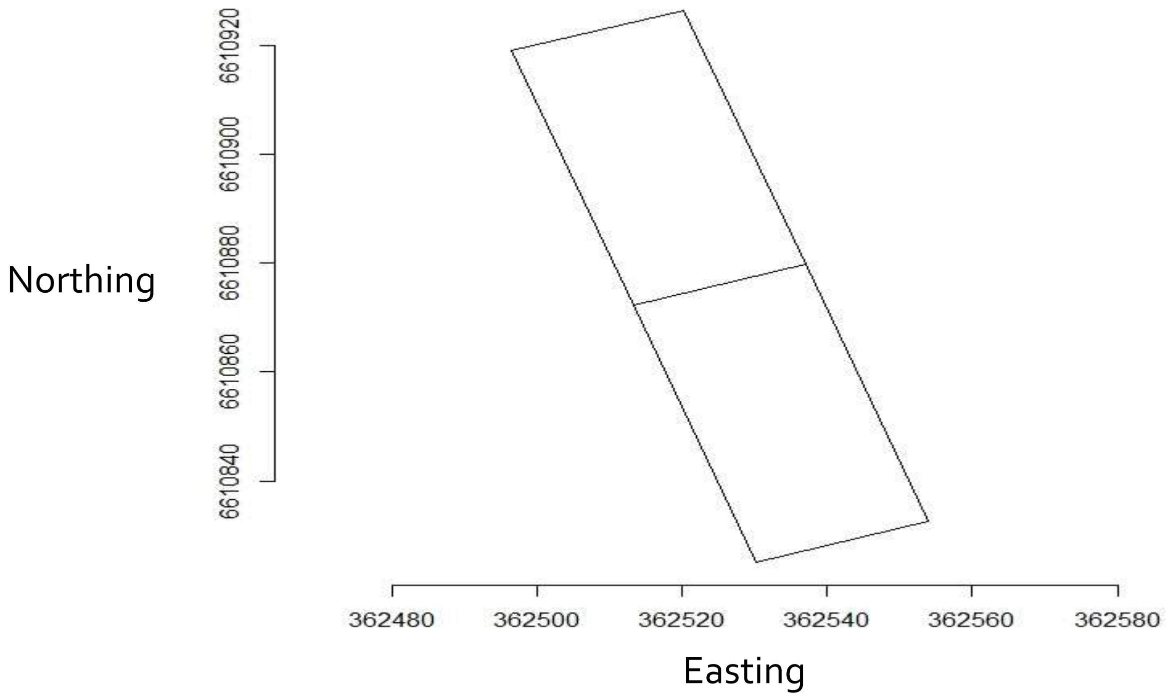
Step 3. Load data and shapefile

```
library(rgdal)

##Load data from CDAX pasture height change csv file:
cdax92<-read.csv('CDAX_92_Change_1.csv', sep=',', header=TRUE)
attach(cdax92)

##Load shapefile using rgdal commands:

R3a <- readOGR(dsn=locate_file, layer="R3") ## load in shapefile for R3
R3_3 <- as(R3a, "SpatialPolygons") ## convert to a polygon

## plot the shapefile
plot(R3_3)
axis(1)
axis(2)
```

Step 3. 3rd ryegrass plot (R3.shp) lower and upper plots combined



Step 4. Add CDAX GPS points (264)

CDAX coordinates in lat/lon; shapefile coordinates UTM.

Need to convert lat/lon to UTM (shapefile)

```
# Setting existing coordinate as lat-long system

cord.dec34 = SpatialPoints(cbind(cdax92$LONG, cdax92$LAT), proj4string =
CRS("+proj=longlat"))

# Transform coordinate to UTM using EPSG=32756 for WGS=84, UTM Zone=56M, Southern
Hemisphere

cord.UTM34 <- spTransform(cord.dec34, CRS("+init=epsg:32756"))

cord.UTM34 ## list on screen the points

points(cord.UTM34, pch=20) # draws points (black dots) on plot
```

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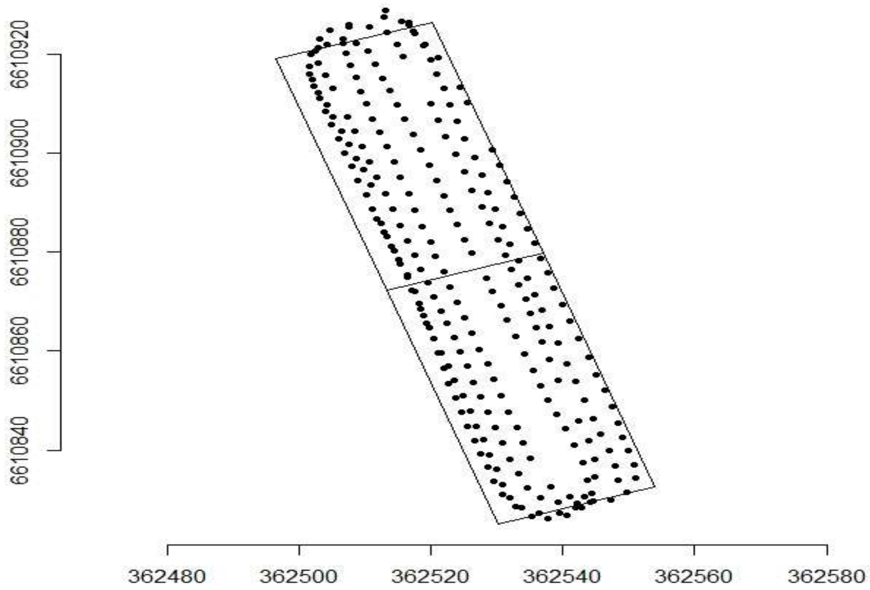
Step 4. Add CDAX GPS points (264)



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Step 5. Create grid

```
## make points a data frame
xy34<-data.frame(cord.UTM34)
colnames(xy34)<-c('X','Y')
cdax3_924<-cbind(cdax92,xy34)

### have to do this - for kriging
p3_14<-cdax3_924
coordinates(p3_14)<-~X+Y

## make points same coordinate projection as shapefile
proj4string(cord.UTM34) <- proj4string(R3a)
```

Step 5. Create grid - continued

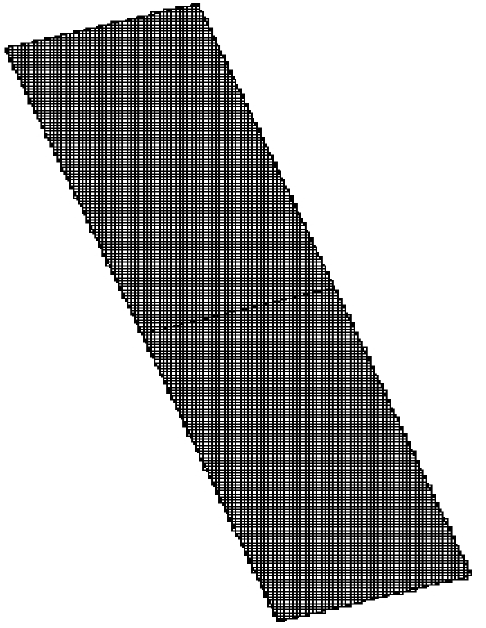
```
bb4 <- bbox(R3a) # get the shapefile corners - 'bounding box'
cs4 <- c(.5, .5) # set cell size for grid - smaller the higher the resolution
cc4 <- bb4[, 1] + (cs4/2)  # cell offset
cd4 <- ceiling(diff(t(bb4))/cs4)  # number of cells per direction
grd4 <- GridTopology(cellcentre.offset=cc4, cellsize=cs4, cells.dim=cd4)
grd4

sp_grd4 <- SpatialGridDataFrame(grd4, data=data.frame(id=1:prod(cd4)),
proj4string=CRS(proj4string(R3a)))
summary(sp_grd4)
## overlay points on grid
over(cord.UTM34, sp_grd4)
```

Step 5. Create grid - continued

```
#To plot the shapefile and the grid:

plot(R3a) ## plot shapefile
spgrdWithin34 <- SpatialPixels(spgrd34[R3a,])
plot(spgrdWithin34, add = T)
```



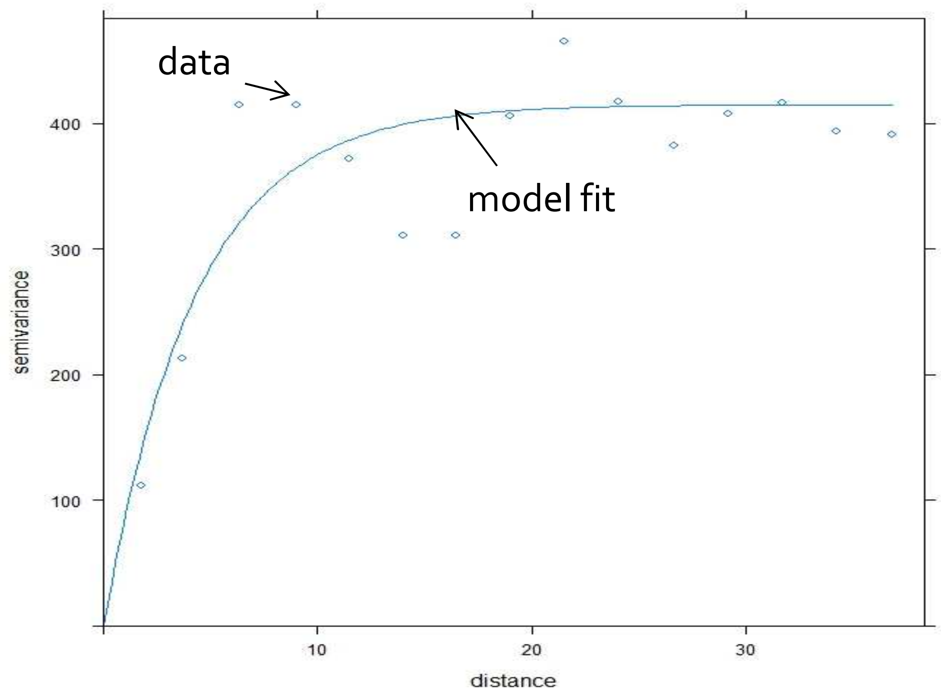
Step 6. Geostatistics - variogram fitting - library(gstat)

Variogram:
Description of the spatial continuity of the data.
It is a discrete function calculated using a measure of variability between pairs of points at various distances.
The exact measure used depends on the variogram type selected

```
v.ok34 = variogram(Height4~1, p3_14)  ## no trend
ok.model34 = fit.variogram(v.ok34, vgm("Exp"))
plot(v.ok34, ok.model34)

## ok = ordinary kriging
```

Variogram plot



Step 7. Creating maps - kriging and plotting

Using gstat

```
h.ok34 = krige(Height4~1, p3_14, spgrdWithin34, model = ok.model34)
pts34 = list("sp.points", p3_14, pch = 20, col = "black")
## plot map
spplot(h.ok34, "var1.pred",sp.layout = list(pts34),col.regions=my_palette,main =
"Pasture height (mm) - R3 (day 4)")
```

Using automap (written in 2013 by a PhD student)

```
k1_14= autoKrige(Height4~1, p3_14, spgrdWithin34) # fits all models from gstat
## plot map
automapPlot(k1_14$krige_output, "var1.pred", sp.layout = list("sp.points", p3_14),
col.regions=my_palette)
```

Also geoR (not shown)

Step 8. Maps of pasture utilisation

spplot – requires lattice; ggplot2 is becoming more popular (ggmap)

(1) Individual plots – height from CDAX (day 0), then simulated day 4, day 8 and day 12
(2) Change in height over time – day 0-4, day 4-8, day 8-12
(3) Combining plots/maps

Create your own colour palette

```
## set up colour ramp for map

my_palette <- colorRampPalette(c("red", "yellow", "green"))(n = 299)
```

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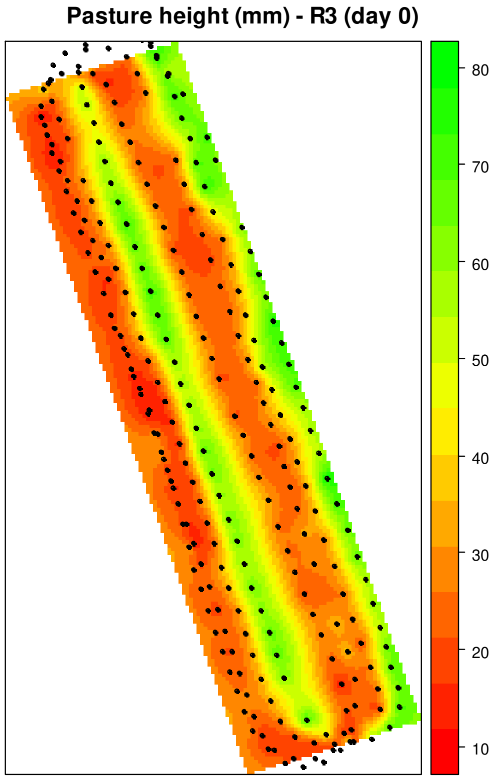
Step 8. Maps of pasture utilisation




```
spplot(h.ok3, "var1.pred",sp.layout =
list(pts3),col.regions=my_palette,main = "Pasture height
(mm) - R3 (day 0)")
```

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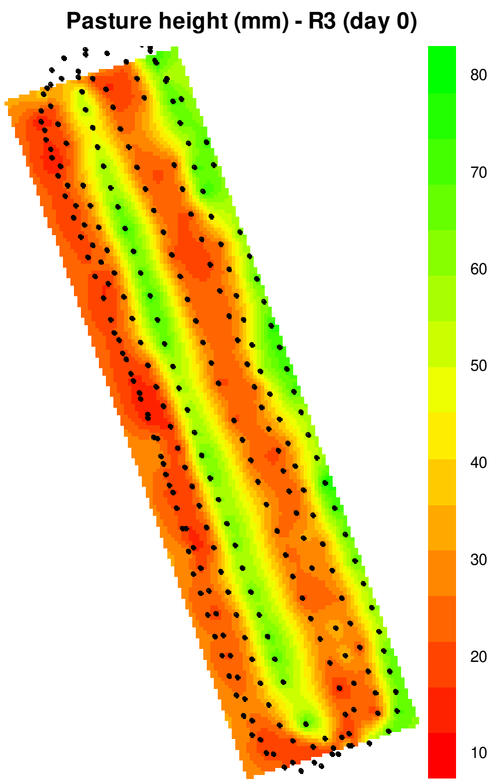
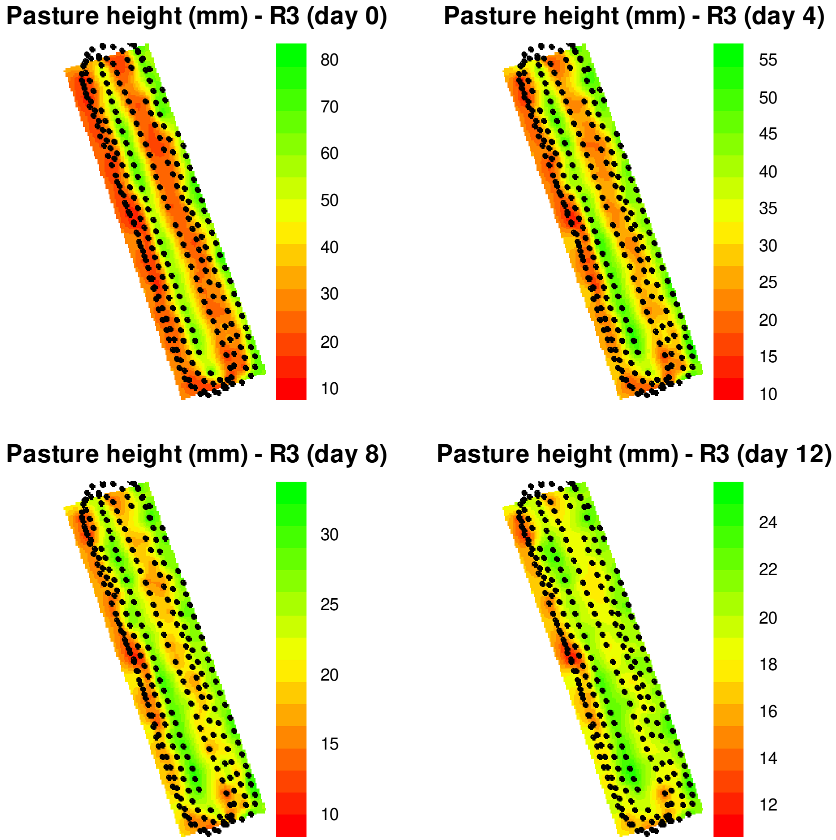
Step 8. Maps of pasture utilisation – no borders



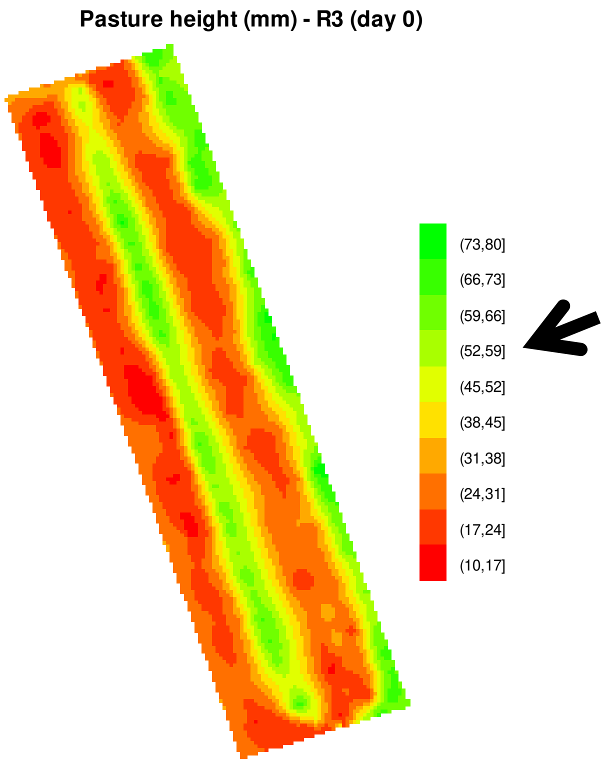

```
spplot(h.ok3, "var1.pred",sp.layout =
list(pts3),col.regions=my_palette,main =
"Pasture height (mm) - R3 (day 0)"),
par.settings = list(axis.line = list(col =
'transparent'))
```

```
### put all 4 maps in one plot

require(gridExtra)
grid.arrange(day0, day4, day8, day12)
```



Changing legend



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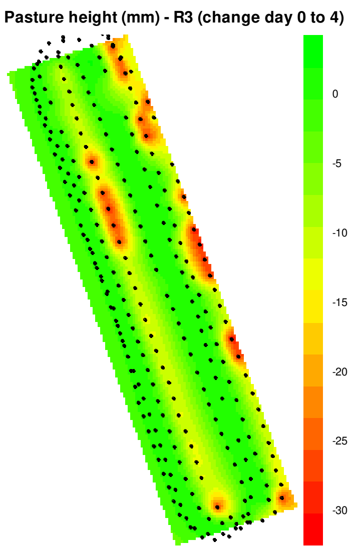
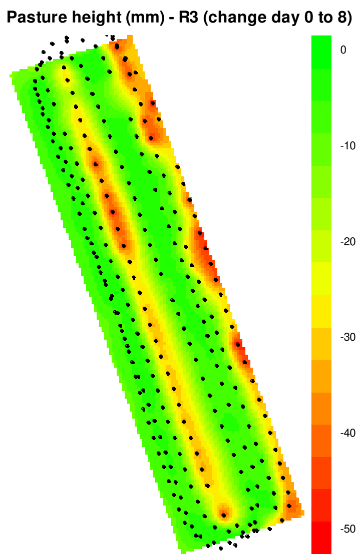
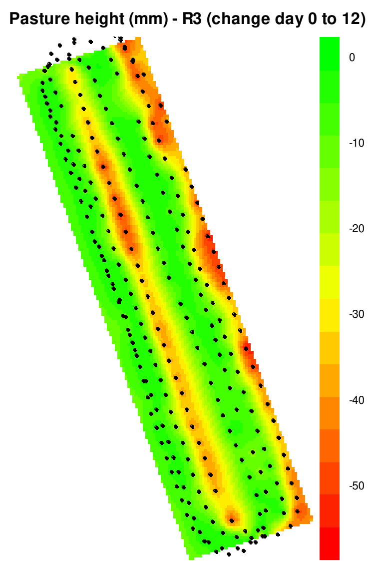
Changing legend - code

```
brks0 <- classIntervals(p3_1$HEIGHT, n = 10, style = "equal")
str(brks0)
brks0$brks
br0<-brks0$brks
offs<-0.0000001
br0[1]<-br0[1]-offs
br0[length(br0)]<-br0[length(br0)]+offs

h.ok3$h.ok3_bracket<-cut(h.ok3$var1.pred,br0)
head(h.ok3$h.ok3_bracket)
class(h.ok3$h.ok3_bracket)

spplot(h.ok3, "h.ok3_bracket",col.regions=my_palette,main = "Pasture height (mm) - R3 (day
0)",par.settings = list(axis.line = list(col = 'transparent')))
```

Change in height over time from days 0-4, 4-8 and 8-12








```
cdax92$Change04<-cdax92$Height4-cdax92$HEIGHT
cdax92$Change08<-cdax92$Height8-cdax92$HEIGHT
cdax92$Change012<-cdax92$Height12-cdax92$HEIGHT
cdax92$Change48<-cdax92$Height8-cdax92$Height4
cdax92$Change812<-cdax92$Height12-cdax92$Height8
```

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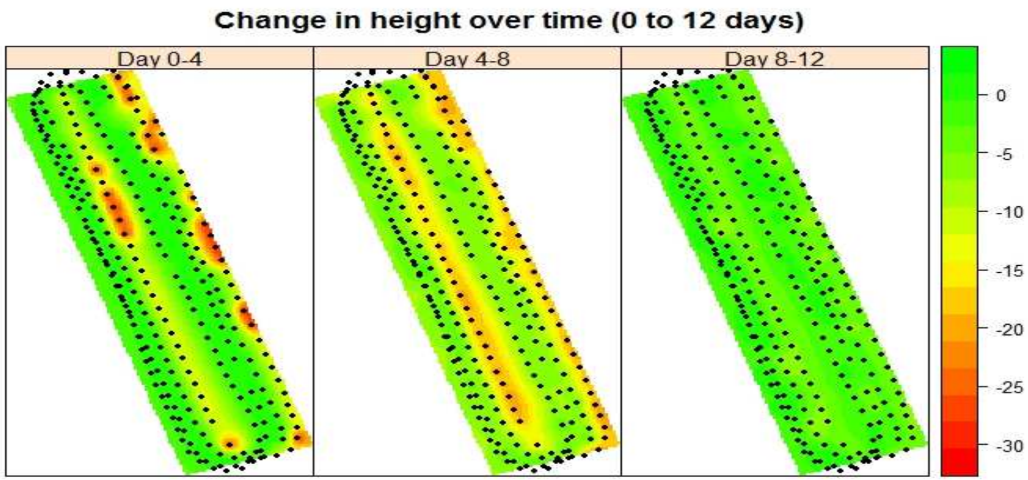
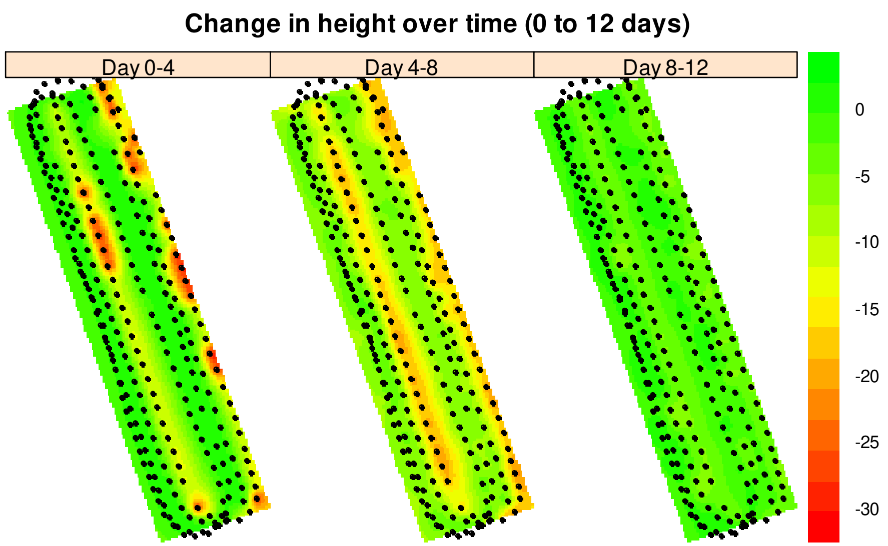
Change in height over time from days 0-4, 4-8 and 8-12 – same key

```
# plot 3 graphs on one plot with same colour key
hgt=h.ok304
hgt[["a"]] = h.ok304[["var1.pred"]]
hgt[["b"]] = h.ok348[["var1.pred"]]
hgt[["c"]] = h.ok3812[["var1.pred"]]
spplot(hgt, c("a", "b", "c"), names.attr = c("Day 0-4", "Day 4-8", "Day 8-12"), as.table = TRUE, main =
"Change in height over time (0 to 12 days)", col.regions=my_palette, sp.layout = list(pts3812))
```



Change in height over time from day 0-4, 4-8 and 8-12 – same key and no border



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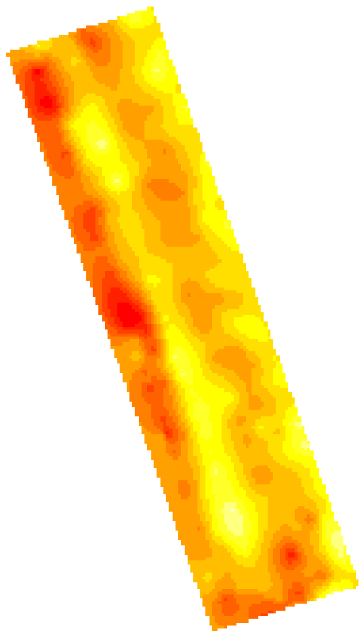
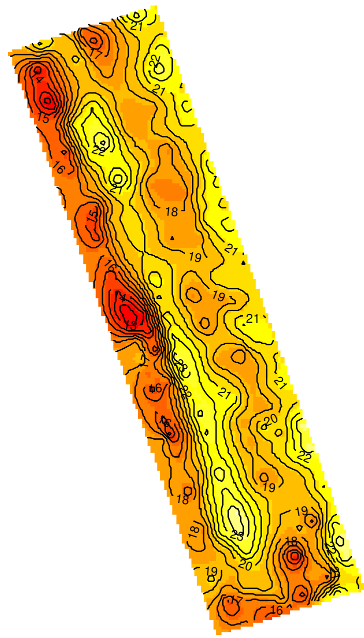
Adding contours – eg day 12

```
image(h.ok312)
```



```
contour(h.ok312)
```

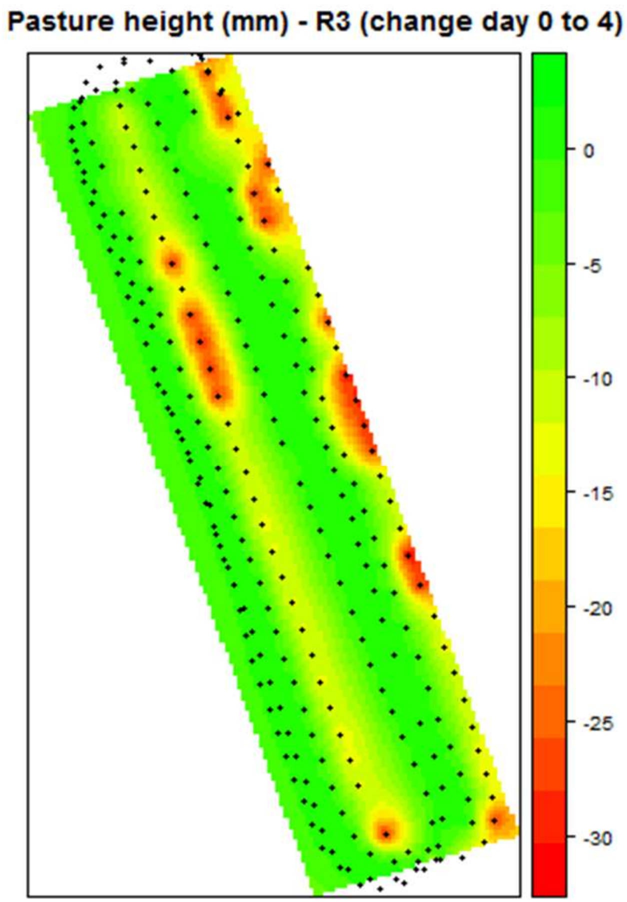
```
image(h.ok312)
contour(h.ok312, add=TRUE, nlev=10)
```



Animation

```
library(animation)

## set some options first
ani.options(interval = 1, nmax = 3)
saveGIF({
for (i in 1:ani.options('nmax')) {
      plot(day04)
      plot(day48)
      plot(day812)
      ani.pause()   ## pause for a while
('interval')
 }
})
```



Where to from here?

- Overlay krige plots onto map image eg ggmap, leaflet
- Overlay animal location (GPS) data
- Analyse
- Create layers – animal and pasture
- The options appear endless

Thank you

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