Land Equivalent Ratio

Evidence for resilience agriculture

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Internship note

Background Study and objective

Climate change impacts are expected to exceed the capacities of smallholder farmers to manage risks, in the absence of adaptations and transformations in the way the food is produced. Management practices and technologies are important building blocks of resilient agriculture. The dataset used by the researchers from ERA has been derived from more than 2,000 scientific papers reporting how the use of new agricultural technologies affect productivity, resilience and greenhouse gas emissions. This dataset including more than hundred thousand observations is linked to more than fifty publicly available environmental datasets.

My objective is to work with these data and if possible, design ways to improve it, connect to other datasets, conduct new analyses using machine learning for instance, answer stakeholder questions, and more than could come up later. I first started to general concept around the data followed by the important concept of Land Equivalent Ratio (LER). LER may be interpreted as the relative area required by sole crops to produce the same yields as achieved in a unit area of intercrop. According to Dariush, et al (2006) an important tool for evaluating the intercropping system is the so-called land equivalent ratio (LER).

Some notes about LER

Intercropping, the cultivation of two or more crop species simultaneously in the same field, has been widely practiced by smallholder farmers in developing countries and is gaining increasing interest in developed countries. The yield advantage of intercropping is often assessed using the land equivalent ratio (LER). An LER value of 1.0, indicating no difference in yield between the intercrop and the collection of monocultures. LER>1 means intercropping is more efficient in land use than sole cropping which can also been interpreted as: in order to produce the same component crop yield as in a unit area of intercrop, a greater land area of sole crops would be needed. While LER of 1.2 indicates that the area planted to monoculture would need to be 20% greater than the area planted to intercrop for the two to produce the combined yield. Application of N fertilizer in intercropping decreases LER when the intercropped species are sown and harvested simultaneously. Land-use efficiency of an intercrop may be compared to that of sole crops using the land equivalent ratio.

A large variation of LER has been found in the literature. However, few studies attempted to investigate reasons for this variation.

This notebook will be filled in as we progress…

LAND EQUIVALENT RATIO

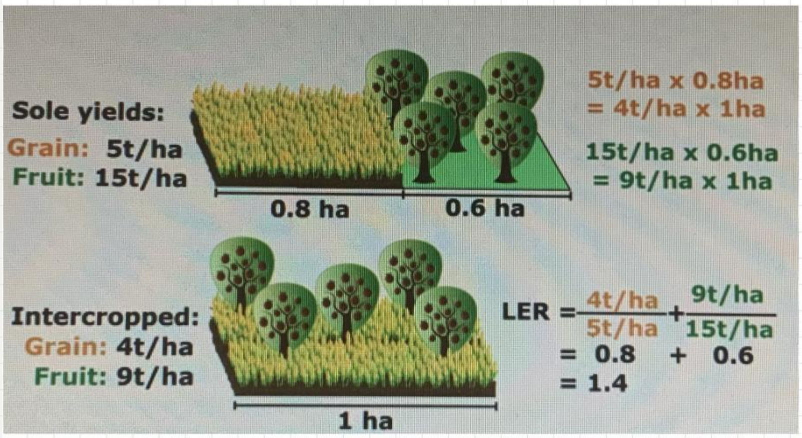
Is a concept in Agriculture that describes The relative land erea required under soil cropping to produce the same yield as under intercropping.

The FAO defines Land equivaland Ratio (LER) as: the ratio of the erea under sole cropping to the erea under intercropping needed to give equal amount of yield at the same management level.

It is the sum of the fractions

$$LER = \frac{\text{intercropped yields}}{\text{sole-crop yield}} = \sum_{i=1}^{m} \frac{IY_i}{SY_i}$$

m = is the number of different crops intercropped
IY_i = is the yield for the i^{th} crop under intercropping
SY_i = is the yield for the i^{th} crop unde solo-crop regime



The table in this section provides yield values for a hypothetical scenario intercropping a grain crop with a fruit tree crop.

The first two columns state the yields for intercropping (IY) and sole yields (SY). The third column, *equivalent area*, column calculates the area of sole cropping land required to achieve the same yield as 1 ha of intercropping, at the same management level.

Crop	Intercropped Yield IY (kg/ha)	Sole Yield SY (kg/ha)	Equivalent area (ha)
Grain	4,000	5,000	0.8
Fruit	9,000	15,000	0.6
	Land equivalent ratio		1.4

The land equivalent ration can be calculated as

$$LER = \sum_{i=1}^{m} \frac{IY_i}{SY_i} = \frac{IY_{grain}}{SY_{grain}} + \frac{IY_{fruit}}{SY_{fruit}} = \frac{4,000}{5,000} + \frac{9,000}{15,000} = 0.8 + 0.6 = 1.4$$

An interpretation of this result would be that a total of 1.4 ha of sole cropping area would be required to produce the same yields as 1 ha of the intercropped system.

Applications

- the LER can be used whenever more than one type of yield can be obtained from the same area

The land equivalent ratio can be used whenever more than one type of yield can be obtained from the same area. This can be intercropping of annual crops (e.g. sorghum and pigeonpea)[1] o combination of annual and perennial crops e.g. in agroforestry systems (e.g. jackfruit and eggplant).[3]

It is also possible to calculate LERs for combinations of plant and non-plant yields, e.g. in agrivoltaic systems.[4]

The table below lists some examples for land equivalent ratios published in scientific journals:

Crops	Country/region	LER	Source
eggplant, jackfruit	Bangladesh	2.17	[3]
cocoa, coconut	Mexico	1.36	[citation needed]
solar electricity, maize	Italy	1.23 - 2.05	[5]
ginger, maize, soybean	Nepal	2.45	[6]
maize, cowpea	Nepal	1.58	[6]
millet, soybean	Nepal	1.40	[6]

Intercropping = growing two or more crops together on the same area of ground

Crop equivalent Yield = The yield of intercrops or crop sequence are converted into equivalent yield of any one crop based on price of the products. It was introduced by Verma and Modgel

INTER CROPPING

It refers to simultaneous production of two or more dissimilar crops in a definite row ratio pattern or row arrangement on the same piece of land at the same time. The base crop, necessarily in distinct row arrangement and its recommended optimum plant population, is suitably combined with the additional plant density of the associated crop. It has better utilization of growth resources than sole cropping. Generally, legumes and non-legumes are grown.

Principles of Intercropping

- When two crops are to be grown together, they are chosen in such away that there is variation in their growth duration. The peak periods of growth of the two crops species should not coincide.
- The associating crop should be complimentary to the main crop.
- The subsidiary crop should be of shorter duration and of faster growing habits, to utilize early slow growing period of main crop.
- The component crops should require similar agronomic practices.
- Erect growing crops should be intercropped with cover crop.
- Erosion permitting crop should be intercropped with erosion resisting crop.
- The component crops should have different rooting pattern and depth of rooting.
- The time of peak nutrient demands of component crops should not overleap
- Competition for light, space, sunshine and air, should be minimum among the component crops.
- compatibility for pests and diseases;

Types of Intercropping

(a)Mixed intercropping: Growing two or more crops simultaneously with no distinct row arrangement. Also referred to as mixed cropping. Ex: Sorghum, pearl millet and cowpea are mixed and broadcasted in rainfed conditions.

(b)Row intercropping: Growing two or more crops simultaneously where one or more crops are planted in rows. Often simply referred to as intercropping. Maize + greengram (1:1), Maize + blackgram (1:1), Groundnut + Redgram (6:1)

(c) Strip intercropping: Growing two or more crops simultaneously in strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Ex. Groundnut + redgram (6:4) strip.

(d) Relay intercropping: Growing two or more crops simultaneously during the part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth, but, before it is ready for harvest. Often simply referred to as relay cropping.

Crop Rotation

Is the practice of growing a series of different types of crops in the same area across a sequence of growing seasons.

Land productivity

In contrast to the discrete **land** use and **land** cover classes, **land productivity** is a continuous variable, which represents **land** cover through vegetation density and vigor. **Land productivity** can indicate the **land's** ability to support and sustain life and is useful for identifying **land** degradation.

Land productivity Falling

Explore "ERAg" and get the "DATA"

```r
```{r}
search()
```
```

```
 [1] ".GlobalEnv"             "package:treemap"        "package:ERAg"           "package:ComplexHeatmap"
 [5] "package:grid"           "package:lme4"           "package:scales"         "package:circlize"
 [9] "package:devtools"       "package:usethis"        "package:viridis"        "package:viridisLite"
[13] "package:colorspace"     "package:colourpicker"   "package:shinyjs"        "package:ggnewscale"
[17] "package:RColorBrewer"   "package:foreign"        "package:rasterVis"      "package:latticeExtra"
[21] "package:terra"          "package:raster"         "package:sf"             "package:rworldxtra"
[25] "package:rworldmap"      "package:sp"             "package:forcats"        "package:stringr"
[29] "package:dplyr"          "package:purrr"          "package:readr"          "package:tibble"
[33] "package:tidyverse"      "package:knitr"          "package:DT"             "package:diagis"
[37] "package:sfsmisc"        "package:MASS"           "package:plyr"           "package:metafor"
[41] "package:Matrix"         "package:shiny"          "package:spatstat"       "package:spatstat.linnet"
[45] "package:spatstat.core"  "package:rpart"          "package:nlme"           "package:spatstat.geom"
[49] "package:spatstat.data"  "package:Hmisc"          "package:Formula"        "package:survival"
[53] "package:lattice"        "package:gridExtra"      "package:tidyr"          "package:miceadds"
[57] "package:mice"           "package:ggrepel"        "package:ggplot2"        "package:doSNOW"
[61] "package:snow"           "package:iterators"      "package:foreach"        "package:data.table"
[65] "package:pacman"         "tools:rstudio"          "package:stats"          "package:graphics"
[69] "package:grDevices"      "package:utils"          "package:datasets"       "package:methods"
[73] "Autoloads"              "package:base"
```

```r
```{r}
ERAg::
```
```

```
AddEcoCrop              {ERAg}
BioClimCodes
CalcClimate             {ERAg}
CreateConceptLevels     {ERAg}
DownloadCHIRPs          {ERAg}
ERA.Compiled
ERA.Data.Versions
ERA_AEZ_MAP_MAT
ERA_BioClim
```

```
AddEcoCrop(Products)

Extracts ecocrop temperature and cycle length variables for a vector of product codes.

Press F1 for additional help
```

```r
```{r}
ERAg::ERA.Compiled
```
```

Description: data.table [107,885 x 142]

Index <int>	Code <chr>	Author <chr>	Date <int>	Journal <chr>	DOI <chr>	Elevation <chr>	Country <chr>
1	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali
5	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali
9	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali
13	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali

Data	
EUCodes	377 obs. of 19 variables
MyCompiled	110421 obs. of 142 variables
OutcomeCodes	102 obs. of 19 variables
PracticeCodes	174 obs. of 14 variables

browseVignettes ("ERAg")

Vignettes found by browseVignettes("ERAg")

Vignettes in package ERAg

- ERA-Climate-Data - HTML source R code
- ERA-Explore - HTML source R code
- ERA-Introduction - HTML source R code
- ERA-Large-Climate-Files - HTML source R code
- ERA Yield Stability - HTML source R code

ERA - Explore

ERA - Introduction

ERA Markdown V3.11 2600 > 0

* Where do we exactly get practice and Subpractice
Pr Name Name

* In ERA-Explore I saw written there are over 1000 subpractices combinaisons ??

* Why is length(unique(Sub Pr name)) not working ?

* What is the meaning of Buffer in the ERA.Compiled

In addition to spacial and temporal Variables
There are three level concepts that are foundation of ERA'S
Experimental classification system:
practices, outcomes and products (Experimental Unit (EU))

$\boxed{\text{practices}}$ ≡ Mangement practices and Technologies

- Agronomic – Crop rotation
- Agroforestry – Livestock dietary supplement
- Livestock interventions – crop rotation

$\boxed{\text{outcomes}}$ ≡ Dependent variables in the experiment

- yield
- benefit cost ratios
- soils Carbon

$\boxed{\text{products}}$ ≡ species or commodity that the outcomes is measured on

- Maize – plant
- Milk – animal prod
- Meat – species

Each is organized hierarchically, where concepts are nested below and above related concepts. This organization allows the user to aggregate or disaggregate data using these fields to explore different questions, from narrow (e.g., how does a Gliricidia-based alley cropping change maize crop yields?) to broad (e.g., considering all products which practices, on average, improve productivity, resilience and mitigation outcomes?) It also facilitates the user to deliver information at the level for the specific users. For example, policy makers refer to agroforestry broadly while farmers are typically more interested in nuanced (disaggregated) results for species and practices. ERA's practices, outcomes, and products hierarchies are unique but recently has been mapped to other ontologies including **AGROVOC** and **AgrO** to increase future interoperability. These mappings will be available in future realeases.

Treatment ≡ A specific combinaison of experimental or control practice

Regular Expression in R

- grep, grepl
- regexpr, gregexpr
- sub, gsub
- regexec

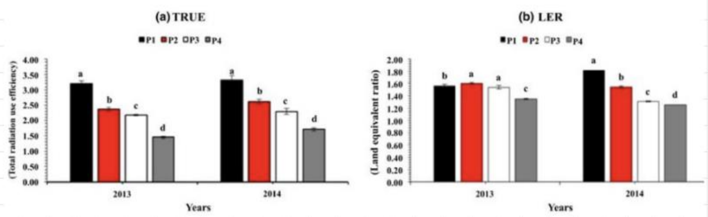
DOI   character DOI (or URL if no DOI available)
DOI = Digital Object Identifier

Questions from my reading

① If we are studying two variety intercroping combi-nations on land use effecienty using LER, what is advisable to do in term of combinations?
Example 50% — 50% ; 10% — 90% ; - - -

② To statistically analyse your Data, do you also use analysis of variance technique appropriate for randomize complete block design with plant density split on planting date ?

③ Having information about the radiation use efficientcy can tell us more about Land Equivalent Ratio ?
because I saw some studies where they also used RUE for almost the same study as for LER



(used in time and space)
④ You didn't speak about the Complementarity of light in the ERA data but it seems to be important to determine the productivity of specie mixtures

⑤ Can I have a better explaination of the following sentence please?

Overall, this thesis shows that the complementary resource use resulting from plant traits diversity and temporal and spatial arrangements of plant mixtures is one of the key factors for high productivity of intercropping.

⑥ So the Biomass (not only the yield) can also help to study the concept of LER?

⑦ Using Meta-Analysis (that you've already done) and functional-structural plant modelling, it's possible to synthesize and explore what factors affect LER and what factors influence the contribution of individual species to LER. Should I dive deeply into functional-Structural PM (without forgetting my weekly task on treemap) or it's not important for now?

⑧ And also possible mechanisms for high LER such that:

- Niche differenciation theory
- Facilitative effects in intercrop
- Agronomic practices
- Statistical approach:
  - Mixed effect Modeling
  - Quantile regression

1) If you are talking about comparing two LER values then perhaps the difference is enough to look at as these are already ratios.

2) Are you proposing to add plant density data? This in not in ERA.Compiled (although we do have for about 1/3 of the data in a different dataset). You'd use a linear or generalized mixed effects model in the lme4 package, or perhaps the rma.mv function in the metafor package. We will be bringing together data from multiple sources, applying a weighting to each observation base on the amount of replication in the study and how many observations a study has contributed to the dataset. And perhaps including random effects for nuisance variables.

3) Few papers report radiation use efficiency, so you would need to calculate it. What is the formula for RUE? (RUE can be defined as the relationship between the accumulations of biomass relative to the light intercepted by the crop.). We have solar radiation data from the NASA POWER dataset summarized for each growing season.

4) The data in ERA is relatively coarse at present. If you think certain variables are important then we may have to revisit the publications to extract data and calculate these. A list of recommendations for variables/outcomes you think are important for understanding diversified system performance is welcome so we can improve future versions of ERA and add to the dataset.

5) To help clarify your project can you please include in your summary document a section that covers:
What question are you trying to answer?
Or what problem are you trying to solve?

6) You could calculate LER for biomass yield if that is important. Also look up Harvest Index. Most people care about product yield though, as if you have good product yield it is highly correlated with a good biomass yield.
Sometimes the biomass is the product (e.g. fodder crops for animal feeds)

7) I would not dive deeply into functional-structural PM we do not have the data to support this. What you can do is describe the data you would need to do this and we can comment on whether this type of approach is feasible in future using a meta-analytical approach.

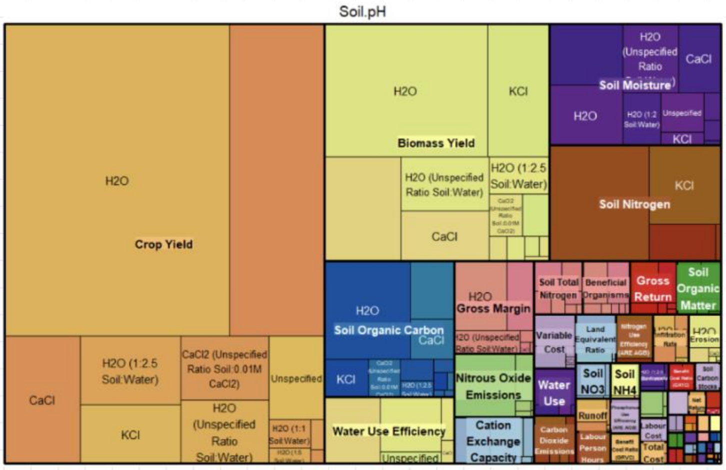
8) We are less interested in the theory and mechanisms of how intercropping and/or rotation work and more interested in the final currency of outcomes. Think about what the end users of your analysis want to know? In your summary document create 3 different end user profiles and suggest a question/problem for each that your analysis will help with.

Treemap

In the Era.Compiled file, we have the Land Equivalent Ratio in the column Out.Subindicator. Let's visualize the representation of each proportion in Out.Subindicator

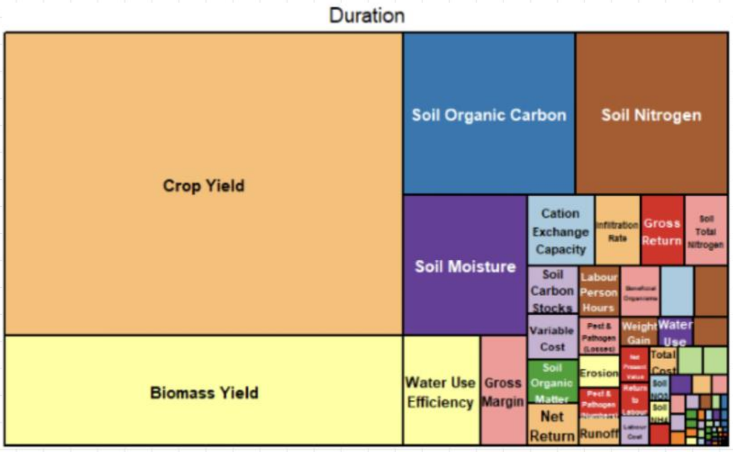
In term of

Soil.PH
and
Soil.PH Method

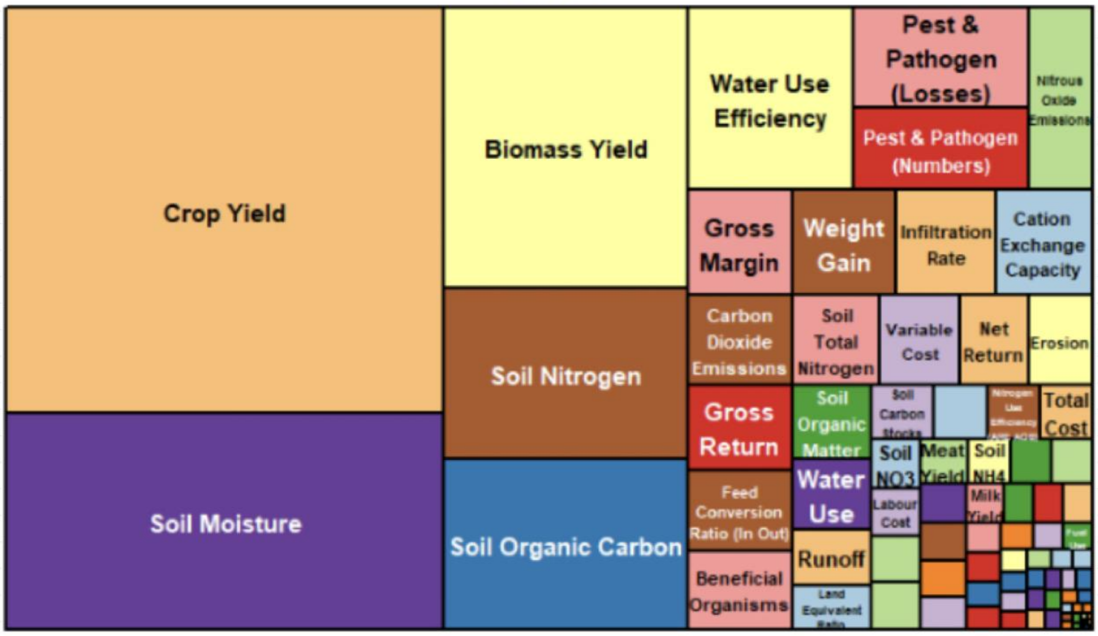


But in term of number of experimental replications (Rep) the system crashed

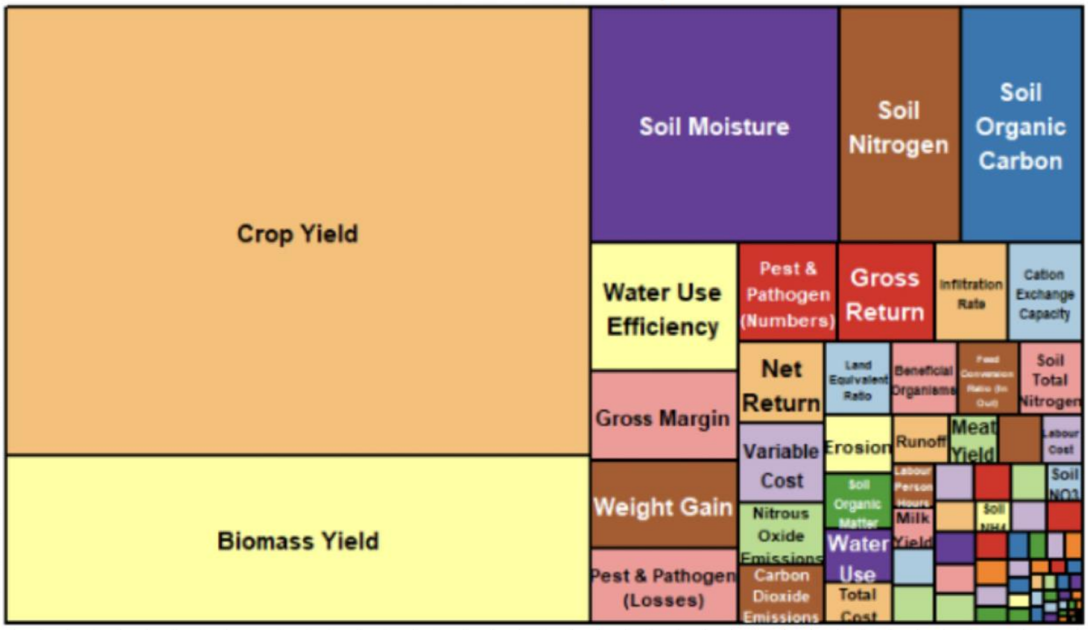
In term of
Duration



Outcode



Mean.Annual.Temp



Subset in ERA

I played around with some subsets with the ERa Compile

```r


require(ERAg)

browseVignettes("ERAg")

ERA.Compiled$Code

ERA.Compiled$Site.Type

ERA.Compiled$Plot.Size

Mydata <- ERAg::ERA.Compiled

#Mydata %>% count(Plot.Size, MeanC, MeanT, sort=TRUE)

Mydata$DOI


getwd()

DjiB <- subset(Mydata, Date == 1997)

#### To subset

DjiB <- subset(Mydata, Date == 1997)
# dataSet[ROWS, COLUMNS]


A1 <- Mydata[Mydata$Date == 1997,  MAT]

A <- Mydata[Mydata$Date == 1997, Elevation, MAT]

```

```r

dim(A1)

A2 <- Mydata[Mydata$Date ==  2009, Elevation, MAT]


head(A2)

A3 <- Mydata[3:8, ]

A4 <- Mydata[3:8, 6]

A5 <- subset(Mydata, Site.ID == "Tafla")

A6 <- subset(Mydata, Site.ID == "Tafla", Code == "NN0001")

A6 <- Mydata[Mydata$Site.ID == "Tafla", Code, MAT]


str(Mydata)


#  Comparing the practices



Mydata[, c(1, 2, 3)]

D1 <- Mydata[, c('PrName', 'Product', 'MeanC', 'MeanT')]


D2 <- Mydata[Mydata$PrName == "Inorganic Fertilizer", c('PrName', 'Product', 'MeanC', 'MeanT')]

D2$Ratio  <- (D2$MeanT/D2$MeanC)
```

Here I have a new column with the ratio Ratio MeanT/MeanC but I couldn't get the Response Ratio (RR) because of the negative ratio with the (Experimental) practice name Inorganic fertilizer for different products

Land_Equivalent_Ratio.Rmd × Analysis_0.Rmd* × D2 × D1 × A5 ×

Filter

	PrName	Product	MeanC	MeanT	Ratio
1	Inorganic Fertilizer	Sorghum	0.99300	1.36500	1.3746224
2	Inorganic Fertilizer	Sorghum	0.99300	1.26400	1.2729104
3	Inorganic Fertilizer	Sorghum	0.99300	1.28900	1.2980866
4	Inorganic Fertilizer	Cotton (Lint or Fibre)	1.12100	1.04400	0.9313113
5	Inorganic Fertilizer	Cotton (Lint or Fibre)	1.12100	1.54400	1.3773417
6	Inorganic Fertilizer	Cotton (Lint or Fibre)	1.12100	1.12000	0.9991079
7	Inorganic Fertilizer	Groundnut or Peanut	0.77500	0.84400	1.0890323
8	Inorganic Fertilizer	Groundnut or Peanut	0.77500	0.82500	1.0645161
9	Inorganic Fertilizer	Groundnut or Peanut	0.77500	0.77500	1.0000000
10	Inorganic Fertilizer	Pearl Millet	0.71800	0.89400	1.2451253
11	Inorganic Fertilizer	Pearl Millet	0.71800	0.96000	1.3370474
12	Inorganic Fertilizer	Pearl Millet	0.71800	1.03900	1.4470752
13	Inorganic Fertilizer	Maize	1.01400	2.29600	2.2642998
14	Inorganic Fertilizer	Maize	1.01400	1.87700	1.8510848
15	Inorganic Fertilizer	Maize	1.01400	2.20400	2.1735700
16	Inorganic Fertilizer	Cotton (Lint or Fibre)	0.86600	1.59500	1.8418014
17	Inorganic Fertilizer	Cotton (Lint or Fibre)	0.86600	1.41000	1.6281755
18	Inorganic Fertilizer	Cotton (Lint or Fibre)	0.86600	1.57100	1.8140878
19	Inorganic Fertilizer	Fonio	1.43000	1.61000	1.1258741
20	Inorganic Fertilizer	Fonio	1.43000	1.51000	1.0559441
21	Inorganic Fertilizer	Fonio	1.53000	1.47000	0.9607843
22	Inorganic Fertilizer	Fonio	1.53000	1.55000	1.0130719

Here I visualize with Site.ID = Tafla

Land_Equivalent_Ratio.Rmd × | Analysis_0.Rmd* × | D2 × | D1 × | A5 × | A6 × | A4 × | Analysis_1.R* × | Mydata × | ERA Markdown V3.11.rmd × | Djibril ER

Filter Cols: « ‹ 0 - 50 › »

	Index	Code	Author	Date	Journal	DOI	Elevation	Country	ISO.3166.1.alpha.3	Site.Type	Site.ID	MAT	MAP
1	25	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
2	29	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
3	33	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
4	37	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
5	41	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
6	45	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
7	26	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
8	27	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
9	28	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600
10	30	NN0001	Bationo A	1997	NUTR CYCL AGROECOSYS	10.1023/a:;1009784812549	NA	Mali	MLI	Farm	Tafla	NA	600

Comparing Some practices : I subset prname , product MeanC and MeanT

Land_Equivalent_Ratio.Rmd × | Analysis_0.Rmd* × | D2 × | D1 × | A

Filter

	PrName	Product	MeanC	MeanT
193	Feed Addition-Feed Processing	Sheep (Meat)	-75.00000	-22.00000
194	Feed Addition-Feed Processing	Sheep (Meat)	-75.00000	3.60000
195	Feed Addition-Feed Processing	Sheep (Meat)	-75.00000	-72.00000
196	Feed Addition-Feed Processing	Sheep (Meat)	-75.00000	-25.00000
197	Feed Addition-Feed Processing	Sheep (Meat)	-5.29000	-1.54000
198	Feed Addition-Feed Processing	Sheep (Meat)	-5.29000	0.25000
199	Feed Addition-Feed Processing	Sheep (Meat)	-5.29000	-5.04000
200	Feed Addition-Feed Processing	Sheep (Meat)	-5.29000	-1.75000
201	Inorganic Fertilizer	Wheat	5.41500	7.36700
202	Inorganic Fertilizer	Wheat	5.41500	7.94000
203	Inorganic Fertilizer	Wheat	3.18700	2.93400
204	Inorganic Fertilizer	Wheat	3.18700	2.83500
205	Irrigation	Wheat	3.40000	2.80000
206	Irrigation	Wheat	4.00000	2.20000
207	Irrigation	Wheat	2.40000	2.20000
208	Irrigation	Wheat	3.60000	3.30000
209	Irrigation	Wheat	3.80000	3.30000
210	Irrigation	Wheat	3.20000	2.60000

We have in total 344 unique practice Names that we could study later depending on our needs

```r
require(dplyr)

D3 <- Mydata[, c('PrName')]

list_unique <- lapply(D3, unique)

print(list_unique)
```

```
> print(list_unique)
$PrName
  [1] "Inorganic Fertilizer"
  [2] "Crop Residue"
  [3] "Feed Processing-Feed Substitution"
  [4] "Irrigation"
  [5] "Feed Addition-Feed Processing"
  [6] "Crop Residue Incorporation"
  [7] "Mulch-Reduced Tillage"
  [8] "Reduced Tillage"
  [9] "Mulch"
 [10] "Storage"
 [11] "Organic Fertilizer"
 [12] "Inorganic Fertilizer-Organic Fertilizer"
 [13] "Crop Residue Incorporation-Inorganic Fertilizer"
 [14] "Improved Varieties"
 [15] "Improved Varieties-Inorganic Fertilizer"
```

Also given the fact that the maximum value of MeanT is 3922825 and the minimum value -46415. For the MeanC we have NA

$\boxed{\text{Yield or RR for different treatments}}$

TID = a short code beginning with T identifying a unique experimental treatment within a study
CID = a short code beginning with C identifying a unique control treatment within a study

	CID	C.NI	C.NO	TID	T.NI	T.NO	yi
1	T10	0		T12	7		0.3181790436
2	T10	0		T13	46		0.2413059107
3	T10	0		T14	46		0.2608913389
4	T10	0		T16	7		-0.0711616546
5	T10	0		T17	23		0.3201553075
6	T10	0		T18	23		-0.0008924588
7	T10	0		T12	12		0.0852894652
8	T10	0		T13	12		0.0625203570
9	T10	0		T14	27		0.0000000000
10	T10	0		T16	14		0.2192362061
11	T10	0		T17	23		0.2904637154
12	T10	0		T18	23		0.3695444221
13	T10	0		T12	83		0.8172655733
14	T10	0		T13	83		0.6157718524
15	T10	0		T14	83		0.7763709861
16	T10	0		T16	44		0.6107441067
17	T10	0		T17	46		0.4874600748
18	T10	0		T18	46		0.5955827297
19	T0.T1.T2.T3.T4.T5.T6.T7.T8	0		T9.T10.T11.T12.T13.T14.T15.T16.T17	15		0.1185597347
20	T0.T1.T2.T3.T4.T5.T6.T7.T8	0		T18.T19.T20.T21.T22.T23.T24.T25.T26	30		0.0544352066
21	T0.T1.T2.T9.T10.T11.T18.T19.T20	0		T3.T4.T5.T12.T13.T14.T21.T22.T23	0		-0.0400053346
22	T0.T1.T2.T9.T10.T11.T18.T19.T20	0		T6.T7.T8.T15.T16.T17.T24.T25.T26	0		0.0129871955

LER for control vs LER for treatment:

LER for practice **A** vs practice **B** cannot be calculated (e.g. mulch vs no-mulch as this yield A/yield B, which is calculated as the response ratio).

And also if Outcome== **LER** then **yi** is the response ration

CID = a short code beginning with C identifying a unique control treatment within a study

C1:C13 = C columns each column can contain a single practice code and together they describe the **control** treatment

T1:T13 = T columns each column can contain a single practice code and together they describe the **experimental** treatment

Let's compare the experimental treatment to the control treatment (Compare the T columns to the C columns) to extract experimental ERA practices that are in the experimental, but not the control treatment.

Some of the controls and experimental treatment are empty in the table. Let's consider for instance the row **No 17**

```
###############################################################################

T.Cols<-paste0("T",1:13)
C.Cols<-paste0("C",1:13)

T.Cols
C.Cols
# Let consider the Row number 95

Mydata[96]

Mydata[96,..T.Cols]

unlist(Mydata[96,..T.Cols])
unique(unlist(Mydata[96,..T.Cols]))

C.Cols<-unique(unlist(Mydata[96,..C.Cols]))
T.Cols<-unique(unlist(Mydata[96,..T.Cols]))

# Remove blanks and h-codes

T.Cols<-T.Cols[!(T.Cols==""|grepl("h",T.Cols)) ]
C.Cols<-C.Cols[!(C.Cols==""|grepl("h",C.Cols)) ]
C.Cols
T.Cols
```

Experimental practices in expe treat but not the control is

b23 = inorganic Fertilizer . Base practices in both b16 and b21

b16 = inorganic Fertilizer

b16 = inorganic Fertilizer

```
> C.Cols
[1] "b21" "b16"
> T.Cols
[1] "b16" "b21" "b23"
```

Experimental practices in experimental treatment but not the control treatment

Is b23 (inorganic fertilizer)

Base practices in both experimental and control treatments are b16 (inorganic fertilizer) and b21 (inorganic fertilizer)

Now let's consider the following subset of data:

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Solo practices in the ERA. Compiled was noted as a single name. For instance "Inputs K" "Input P" whereas Combination practices are re cognised with "–" symbol eg "Input K–Input P"

```
##### No. combination practices

```{r}
nrow(ERA.Compiled[grepl("-",SubPrName)])
```

[1] 46406

No. solo practices

```{r}
nrow(ERA.Compiled[!grepl("-",SubPrName)])

```

[1] 61511

```{r}
nrow(ERA.Compiled)

```

[1] 107917

To make sure we have the same number of total rows

```{r}
nrow(ERA.Compiled[!grepl("-",SubPrName)]) + nrow(ERA.Compiled[grepl("-",SubPrName)])
```
```

1. Subset the data by LER outcome
2. Conduct data exploration for the subset data:
    a. What crops (EU)
    b. What diversity
    c. What practices
    d. Make a map of where data are

ANALYZING DATA

We will analyze outcomes for effectiveness of Land Equivalent Ratio and related practices

We can start by exploring the ERA Practice Codes to check where we might get the names of practices we are interested in.

```
PracticeCodes[,unique(Theme)]
```

```
[1] "Agroforestry"       "Soil Management"    "Water Management"   "Crop Management"    "Genetic improvement" "Nutrient Management"
[7] "Energy"             "Animals"            "Postharvest"        "Non-CSA"
```

We used Theme because it's the highest level of organization for practice. So Agroforestry is a nice place to look.

Let's look at the overlapping practices with this Theme

```
PracticeCodes[Theme=="Agroforestry",unique(Practice)]
```

```
[1] "FMNR"                   "Alleycropping"             "Parklands"              "Boundary Planting"
[5] "Silvopasture"           "Multistrata Agroforestry"  "Agroforestry Pruning"   "Agroforestry Fallow"
[9] "Other Agroforestry"
```

We can now check the Subpractices of Agroforestry theme.

Let's see what are there in the Agroforestry pruning which is a subpractice of Agroforestry practice

PracticeCodes[Practice=="Agroforestry Pruning",unique(Subpractice)]

```
 [1] "Tree Prunings Applied (Unspecified)"     "Tree Prunings Mulched (Unspecified)"     "Tree Prunings Incorporated (Unspecified)"
 [4] "Tree Prunings Applied (N fixing)"        "Tree Prunings Mulched (N fixing)"        "Tree Prunings Incorporated (N fixing)"
 [7] "Tree Prunings Applied (Non N fixing)"    "Tree Prunings Mulched (Non N fixing)"    "Tree Prunings Incorporated (Non N fixing)"
[10] "Tree Pruning (Fate Unknown)"
```

Many of these are close to our definition such as

Tree Prunings Applied (Unspecified): Prunings (leaves, branches, etc.) of an unidentified woody plant were retained/returned to the cropping area, but it is unknown if they were mulched or incorporated.

Tree Prunings Mulched (Unspecified): Prunings (leaves, branches, etc.) of an unidentified woody plant were applied to the cropping area as mulch (prunings on the surface).

Tree Prunings Incorporated (Unspecified): Prunings (leaves, branches, etc.) of an unidentified woody plant were applied to the cropping area and incorporated into the soil (e.g., by ploughing).

Which is not easy to track.

Let's subset the Data by LER outcomes

Let's first display the list of all outcomes subindicat
where we could find Land Equivalent Ration among
Them

1) Let's subset the data by LER Outcome

ERAg::ERA.Compiled[,unique(Out.SubInd)]

```
[61] "Nitrogen Use Efficiency (Isotopic AGB)"   "Protein Conversion Ratio (In Out)"
[63] "Methane Emissions"                         "CO2 Equivalent Emissions"
[65] "Land Equivalent Ratio"                     "Benefit Cost Ratio (NRVC)"
[67] "Net Present Value"                         "Phosphorus Use Efficiency (ARE Product)"
[69] "Return on Investment"                      "Fixed Cost"
[71] "Internal Rate of Return"                   "Nitrogen Agronomic Efficiency (AGB)"
```

We can observe 85 unique outSubin but we are only interested in LER. Now we have the following subset of Data

Mydata <- ERAg::ERA.Compiled

Sub1 <- Mydata[Mydata$Out.SubInd == "Land Equivalent Ratio",]

Sub1$Out.SubInd

```
[741] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[746] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[751] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[756] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[761] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[766] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[771] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[776] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[781] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[786] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[791] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[796] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[801] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
[806] "Land Equivalent Ratio" "Land Equivalent Ratio" "Land Equivalent Ratio"
```

We have a total of 808 of them

```
> length(Sub1$Out.SubInd)
[1] 808
```

2) Now let's conduct the data exploration for the subset

a) Let's check what crops (EU) are there

products are final high level in ERA, which are also called experiment unit (EUs). products as mentioned, refer to what is being measured. this is typically a plant species or animal product.

products codes, Their names and definitions are found in the EU Codes. Let's visualize the following:

knitr::kable(EUCodes[c(3,5,34,66),c(1,2,3,4,5,8)]):

```
|EU  |Product.Type |Product.Type.Code |Product.Subtype |Product.Subtype.Code |Product.Simple |
|:---|:------------|:-----------------|:---------------|:--------------------|:--------------|
|a1  |Animal       |Animal            |Animal (Other)  |AnOt                 |Other Animal   |
|a6  |Animal       |Animal            |Camelid         |Cam                  |Camel          |
|a26 |Animal       |Animal            |Seafood         |Sf                   |Cephalapod     |
|d11 |Plant        |Plant             |Fibre & Wood    |FiWo                 |Ramie          |
```

We can also check the products from our subset Data and get a new subset

Sub2 <- knitr::kable(Mydata[Mydata$Out.SubInd == "Land Equivalent Ratio", Out.SubInd, Product])

Sub2

```
|Product                                                              |Out.SubInd            |
|:--------------------------------------------------------------------|:---------------------|
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
|Agroforestry Residues-Maize                                          |Land Equivalent Ratio |
```

Let's now check the number of unique products for the outcomes LER. These will be all the unique products we have for the out.SubIn LER in the ERA Dataset

```
 [1] "Agroforestry Residues-Maize"
 [2] "Agroforestry Residues-Cowpea"
 [3] "Barley-Fodder (Trees)"
 [4] "Fodder (Trees)-Pearl Millet"
 [5] "Rye-Unspecified Fodder (Grass)"
 [6] "Fodder (Trees)-Unspecified Fodder (Grass)"
 [7] "Gum Arabic-Roselle or Hibiscus (Fibre)"
 [8] "Gum Arabic-Sorghum"
 [9] "Gum Arabic-Sesame Seed"
[50] "Maize"
[51] "Maize-Mung Bean or Green Gram"
[52] "Groundnut or Peanut-Maize"
[53] "Cassava or Yuca-Okra"
[54] "Cassava or Yuca-Pepper (Seed)"
[55] "Cassava or Yuca-Pumpkin & Winter Squash"
[56] "Lablab-Maize"
[57] "Lablab"
[58] "Barley-Broad or Fava Bean"
[59] "Calabash or Bottle Gourd-Sorghum"
```

We have 59 different unique products

b) Let's look at the diversity

Diversity is a description of crop diversification in time and/or space (i.e. intercropping and/or rotation). Let's view the unique Diversity for the LER

```
> Sub1[,unique(Diversity)]
 [1] "Leucaena leucocephala-Maize"                 "Senna Senna siamea-Maize"
 [4] "Grevillea robusta-Cowpea"                    ""
 [7] "Acacia-Sorghum"                              "Acacia-Sesame"
[10] "Black Pepper-Grevillea robusta"              "Pearl millet-Cowpea"
[13] "Yam-Maize-Mucuna"                            "Yam-Maize-Lima Bean"
[16] "Yam-Maize-Cassava"                           "Yam-Maize-Cassava-Mucuna"
[19] "Yam-Maize-Cassava-African Yam Bean"          "Cassava-Maize"
[22] "Cassava-Maize-Lima Bean"                     "Cassava-Maize-African Yam Bean"
[25] "Maize-Cowpea"                                "Maize-Bean"
[28] "Maize-Amaranth"                              "Cassava-Maize-Melon"
[31] "Cassava-Maize-Cowpea"                        "Melon-Maize"
[34] "Sorghum-Bean"                                "Sorghum-Soybean"
[37] "cowpea-millet"                               "Sorghum-Cowpea"
[40] "Sorghum-Sesame-Acacia senegal"               "Black Pepper-Cardamom-Gliricidia sepium"
[43] "Cowpea-Pearl Millet"                         "Cotton-Wheat"
[46] "Finger Millet-Mung Bean"                     "Common Bean-Okra"
[49] "Common Bean-Maize-Okra"                      "Butter Bean-Maize"
[52] "Cassava-Cowpea"                              "Common Bean-Maize"
[55] "Crotalaria ochrolueca-Maize"                 "Maize-Mung Bean"
[58] "Desmodium intortum-Maize"                    "Maize-Pigeon Pea"
```

We have in total **67 unique Diversity** for the **808 Out. LER**

intercropping can be identified with a "-" or ".." and "/" indicates different growing seasons. So we have:

788 intercropping,

```
> nrow(Sub1[grepl("-",Diversity)])
[1] 788
```

20 sole cropping,

```
> nrow(Sub1[!grepl("-",Diversity)])
[1] 20
```

27 different growing seasons,

```
> nrow(Sub1[grepl("/",Diversity)])
[1] 27
```

781 Single growing seasons,

```
> nrow(Sub1[!grepl("/",Diversity)])
[1] 781
```

c) Let's look at the Practices

We can carry out a study similar to the previous one to have the necessary information about practices for the LER outcome.

Let's consider the top 10 including

- out.SubInd
- Out.SubInd.Code
- PrName
- PrName Code
- Product Simple
- Product Simple Code

So we have

knitr::kable(head(unique(Sub1[,list(Out.SubInd,Out.SubInd.Code,PrName,PrName.Code,Product.Simple,Product.Simple.Code)]), 10))

Out.SubInd	Out.SubInd.Code	PrName	PrName.Code	Product.Simple	Product.Simple.Code
Land Equivalent Ratio	LER	Agroforestry Pruning-Alleycropping	Al/AP	Agroforestry Residues-Maize	AgRe/Mai
Land Equivalent Ratio	LER	Alleycropping	Al	Agroforestry Residues-Maize	AgRe/Mai
Land Equivalent Ratio	LER	Alleycropping	Al	Agroforestry Residues-Cowpea	AgRe/CoPe
Land Equivalent Ratio	LER	Alleycropping-Improved Varieties-Inorganic Fertilizer	Al/IF/IV	Barley-Fodder Tree	Bar/FoTr
Land Equivalent Ratio	LER	Alleycropping-Inorganic Fertilizer-Irrigation	Al/IF/Ir	Fodder Tree-Pearl Millet	FoTr/PeMi
Land Equivalent Ratio	LER	Alleycropping-Improved Varieties-Inorganic Fertilizer	Al/IF/IV	Rye-Seed	Rye/UnGr
Land Equivalent Ratio	LER	Alleycropping-Improved Varieties-Inorganic Fertilizer	Al/IF/IV	Fodder Tree-Seed	FoTr/UnGr
Land Equivalent Ratio	LER	Alleycropping-Inorganic Fertilizer-Irrigation	Al/IF/Ir	Rye-Seed	Rye/UnGr
Land Equivalent Ratio	LER	Alleycropping-Inorganic Fertilizer	Al/IF	Fodder Tree-Pearl Millet	FoTr/PeMi
Land Equivalent Ratio	LER	Alleycropping-Inorganic Fertilizer-Irrigation	Al/IF/Ir	Fodder Tree-Seed	FoTr/UnGr

So the unique list of Practices associated to this

knitr::kable(unique(Sub1[,list(PrName,PrName.Code)]))

PrName	PrName.Code
Agroforestry Pruning-Alleycropping	Al/AP
Alleycropping	Al
Alleycropping-Improved Varieties-Inorganic Fertilizer	Al/IF/IV
Alleycropping-Inorganic Fertilizer-Irrigation	Al/IF/Ir
Alleycropping-Inorganic Fertilizer	Al/IF
Intercropping	In
Inorganic Fertilizer-Intercropping	IF/In
Inorganic Fertilizer	IF
Improved Varieties-Intercropping	In/IV
Reduced Tillage	RT
Parklands	Pa
Green Manure	GM
Crop Rotation-Intercropping	CRo/In
Agroforestry Pruning-Intercropping	AP/In
Alleycropping-Intercropping	Al/In
Organic Fertilizer	OF
Inorganic Fertilizer-Organic Fertilizer	IF/OF

So we have in total **19 unique Practices** for the **Out.SubIndicator**

d) Let's visualize this in a Graph

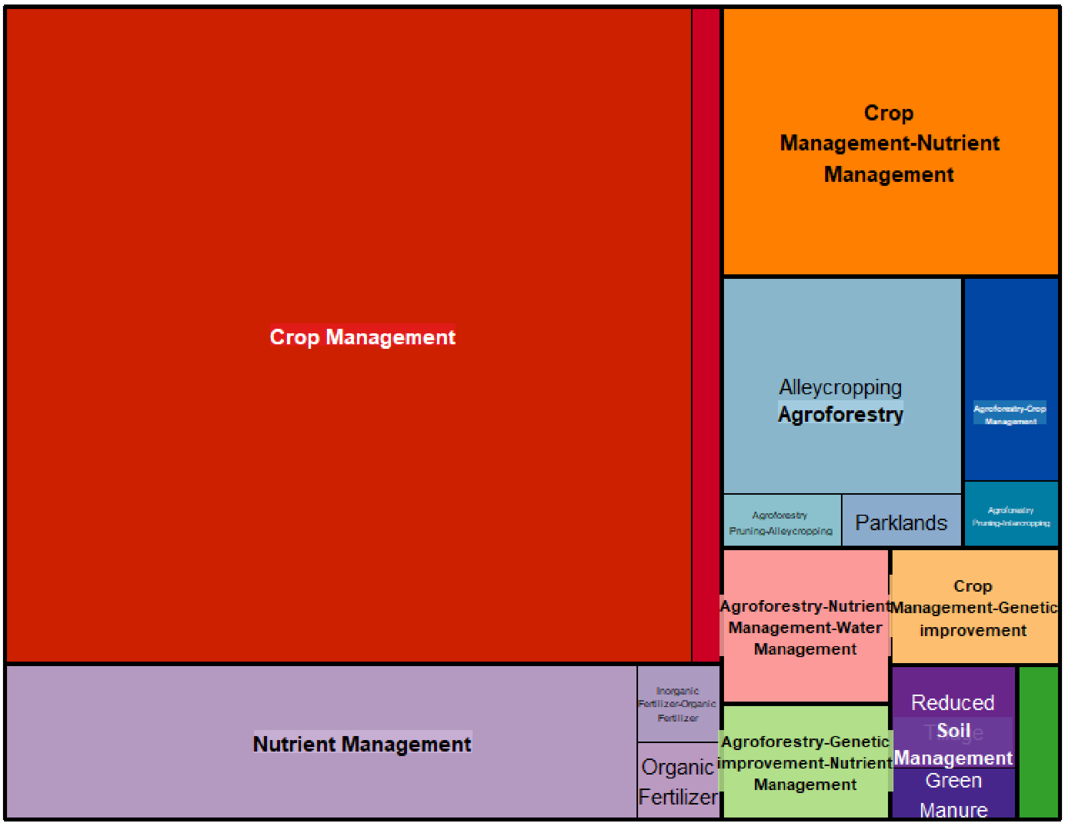
- **With the treemap function:**

Let's us start by Creating a New Subset involving
Code, Pr Name, Sub Pr Name, and Theme.
Code will help us to identify the Number of practices by
Taking unique (Code)

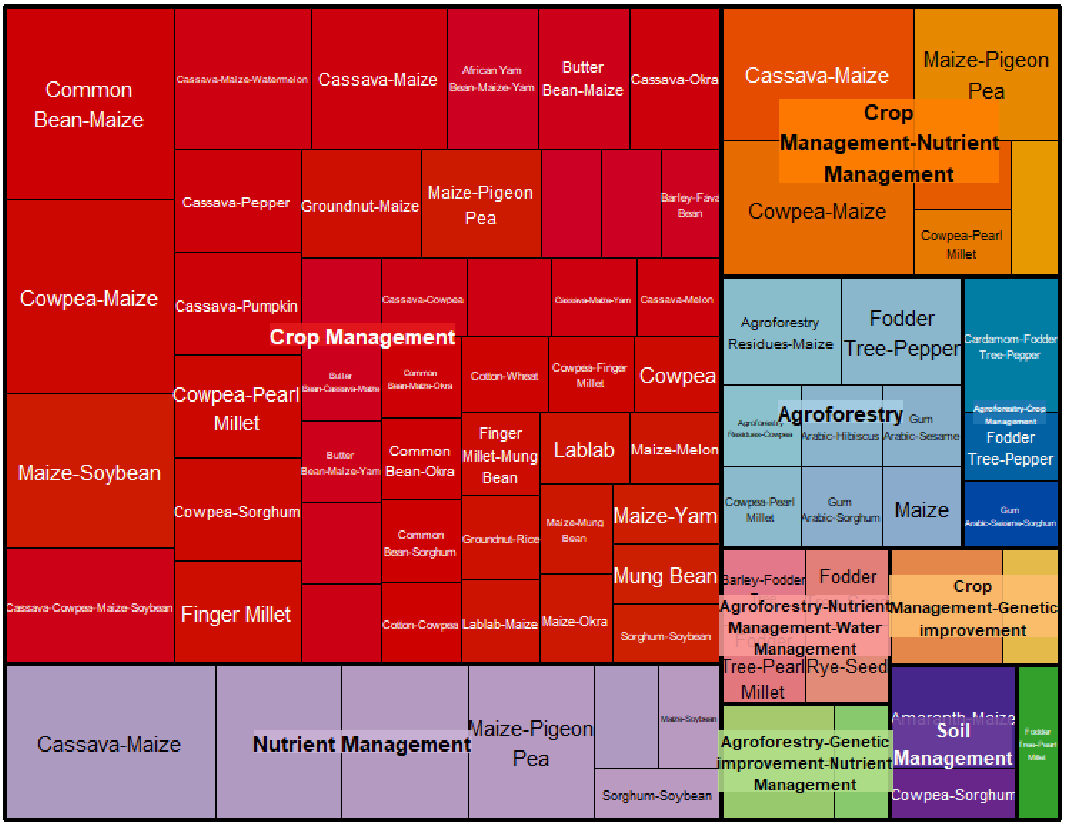
Sub_4 <- Sub1[,list(Code, PrName, SubPrName,Theme, Product.Simple, Side.ID)]

Sub_Data.Pracs<-
Sub_4[,list(Number.of.Studies=length(unique(Code))),by=list(SubPrName,PrName,Theme)]

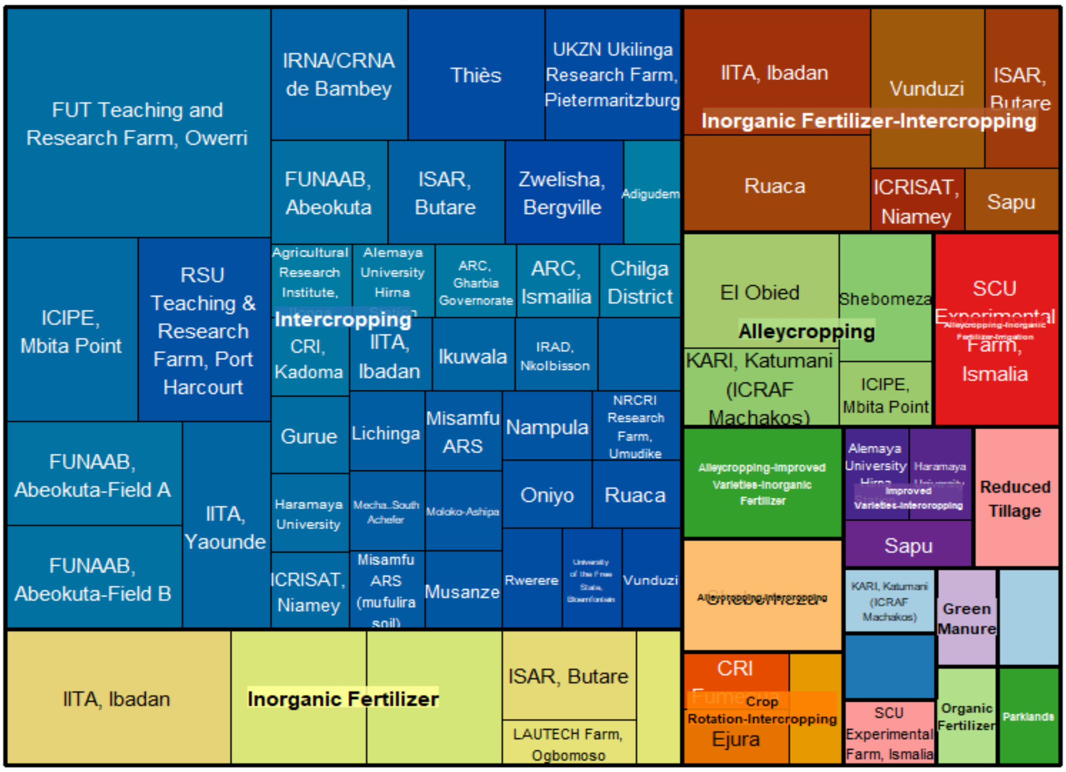
Number of Studies reporting our Subset Data (Practices and Theme)



Number of Studies reporting our Subset Data (Theme and Practices)



Number of Studies reporting our Subset Data (Practices on Different Site ID)



6/25/2021

1) Let's analyze **Outcomes** for the efficiency of **organic fertilizer** practices using **Inputs manure**.

Manure is organic matter that is used as organic fertilizer in agriculture. Most manure consists of animal feces; other sources include compost and green manure.

So this is just animal dung for fertilizing land

If we Explore The different practices in ERA using the ERA practiceCodes, We would be able to see where the practices we interested in are. So we have

"Agroforestry", "Soil Management", "Water Management", "Crop Management" "Genetic improvement" "**Nutrient Management**", "Energy" "Animals" "Postharvest" "Non-CSA" .

Nutriment Management is a good place to check for this study. We can then look at the practices nesting withing this theme

"Inorganic Fertilizer" "**Organic Fertilizer**" "Fertilizer"

So we realise that the Organic Fertilizer practice is in the Nutriment Management theme. We can also look at the Subpractices nested within these practices in order to see what these are for Organic Fertilizer

"Compost" "**Manure**" "Kraaling or Parcage" "Organic (Other)" "Ash" "Biosolids"

Therefore, only one of these practices Manure has to be checked. Let's recall his definition first

```
PracticeCodes[Subpractice %in% "Manure",Definition]
```

Manure: Application of animal manure to the field, typically to test application timing or amount. This does not include biosolids such as sewage which have their own practice codes.

Let' check the Data availability

We can start by seeing what data we have in ERA on these practices

```
(PtPracs<-Mydata[grepl(paste("Manure",collapse = "|"),SubPrName),SubPrName]   %>%   table %>%   sort(decreasing = T))
```

```
                                                              Inputs Manure
                                                                       5094
                                                Green Manure (Nfix; Space)
                                                                       1026
                                                    Inputs Manure-Inputs N
                                                                        746
                                                 Green Manure (Nfix; Time)
                                                                        597
                                  Inputs K-Inputs Manure-Inputs N-Inputs P
                                                                        488
                                   Green Manure (Nfix; Space)-Mulch (noID)
                                                                        361
                           Green Manure (Nfix; Time)-Residue Incorp (noID)
                                                                        359
                                             Green Manure (nonNfix; Space)
                                                                        301
                  Green Manure (Nfix; Space)-Green Manure (nonNfix; Space)
                                                                        262
                                                    Inputs Manure-Inputs P
                                                                        237
                      Inputs K-Inputs Manure-Inputs N-Inputs P-Inputs Urea
                                                                        208
                                           Inputs Manure-Inputs N-Inputs P
                                                                        202
                                        Inputs Manure-Inputs P-Inputs Urea
                                                                        185
                               Inputs K-Inputs Manure-Inputs P-Inputs Urea
                                                                        168
                                    Green Manure (Nfix; Time)-Mulch (noID)
                                                                        156
                                     Green Manure (Nfix; Time)-Seed Improv
                                                                        155
                                              Inputs Kraaling-Inputs Manure
                                                                        144
Green Manure (Nfix; Time)-Inputs K-Inputs N-Inputs P-Inputs Urea-Rotation (nonNfix)
                                                                        138
```

```
Inputs K-Inputs Manure-Inputs N-Inputs P-Inputs Urea-Intercrop (nonNfix)
                                                                       1
         Inputs K-Inputs Manure-Inputs N-Inputs P-Mulch (noID)-NoTill-pH
                                                                       1
                                              Inputs Manure-Inputs Micro-pH
                                                                       1
         Inputs Manure-Inputs N-Inputs P-Inputs Urea-Mulch (noID)-NoTill
                                                                       1
                      Inputs Manure-Inputs N-Inputs P-Mulch (noID)-NoTill
                                                                       1
                         Inputs Manure-Inputs N-Inputs P-Rotation (Mixed)
                                                                       1
                     Inputs Manure-Inputs P-Inputs Urea-Intercrop (Mixed)
                                                                       1
                      Inputs Manure-Inputs P-Inputs Urea-MinTill-Zai Pits
                                                                       1
                 Inputs Manure-Inputs P-Inputs Urea-Residue Incorp (noID)
                                                                       1
                                     Inputs Manure-Inputs Urea-Seed Improv
                                                                       1
```

Using Treemap will be a good way of visualizing the above data. We can subset the data to see where we have a reasonable number of observations at least 100

```
> PtPracs<-PtPracs[PtPracs>=100] %>% names
> PtPracs
 [1] "Inputs Manure"
 [2] "Green Manure (Nfix; Space)"
 [3] "Inputs Manure-Inputs N"
 [4] "Green Manure (Nfix; Time)"
 [5] "Inputs K-Inputs Manure-Inputs N-Inputs P"
 [6] "Green Manure (Nfix; Space)-Mulch (noID)"
 [7] "Green Manure (Nfix; Time)-Residue Incorp (noID)"
 [8] "Green Manure (nonNfix; Space)"
 [9] "Green Manure (Nfix; Space)-Green Manure (nonNfix; Space)"
[10] "Inputs Manure-Inputs P"
[11] "Inputs K-Inputs Manure-Inputs N-Inputs P-Inputs Urea"
[12] "Inputs Manure-Inputs N-Inputs P"
[13] "Inputs Manure-Inputs P-Inputs Urea"
[14] "Inputs K-Inputs Manure-Inputs P-Inputs Urea"
[15] "Green Manure (Nfix; Time)-Mulch (noID)"
[16] "Green Manure (Nfix; Time)-Seed Improv"
[17] "Inputs Kraaling-Inputs Manure"
[18] "Green Manure (Nfix; Time)-Inputs K-Inputs N-Inputs P-Inputs Urea-Rotation (nonNfix)"
[19] "Inputs Manure-Mulch (Nfix)-NoTill"
[20] "Inputs Manure-Inputs Micro"
[21] "Inputs Manure-Mulch (nonNfix)"
```

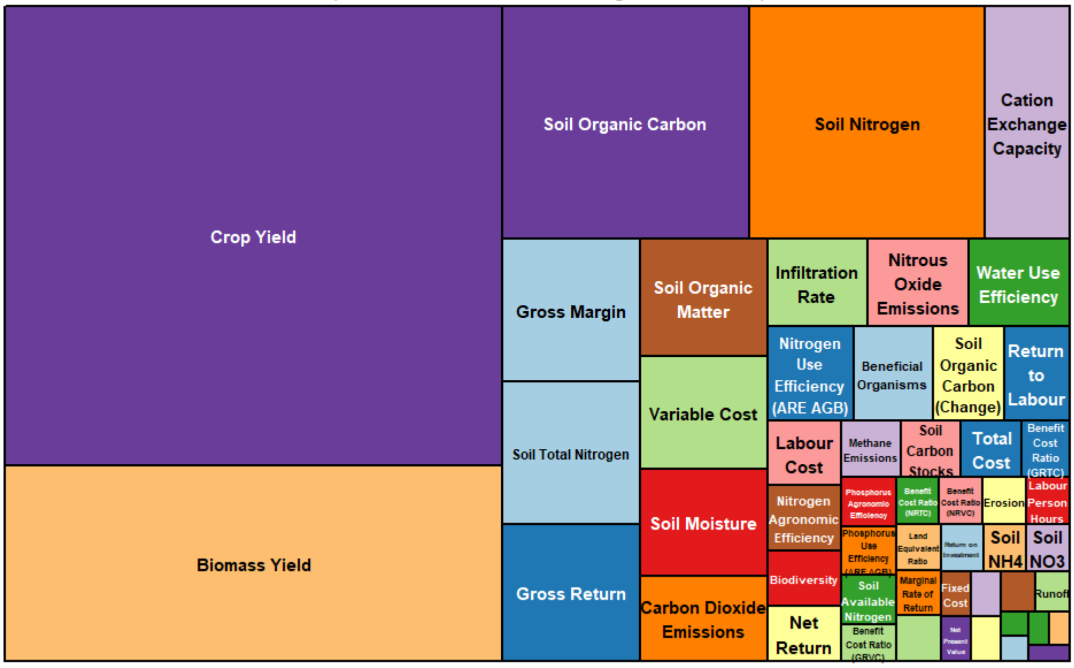
Let's now see what outcomes do we have data for

ERA.M <-Mydata[SubPrName %in% PtPracs]

ERA.M.Out <- ERA.M[,list(N.Studies=length(unique(Code))),by=list(SubPrName,Out.SubInd)]

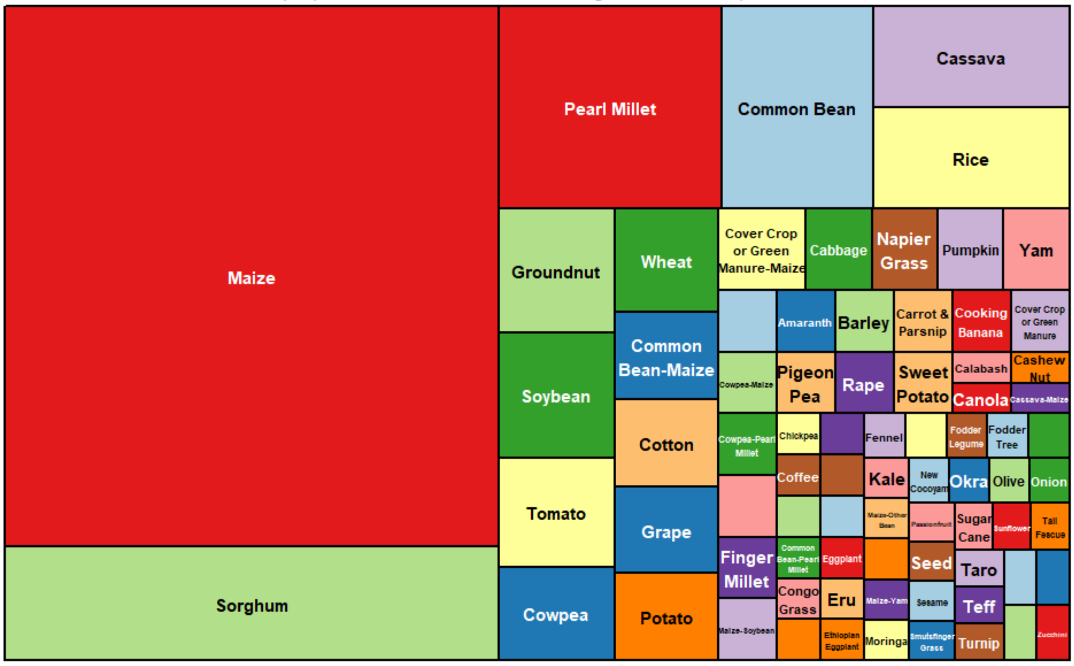
ERA.M	11172 obs. of 142 variables
ERA.M.Out	245 obs. of 3 variables

Outcomes present for Manure-based Organic Fertilizer practices

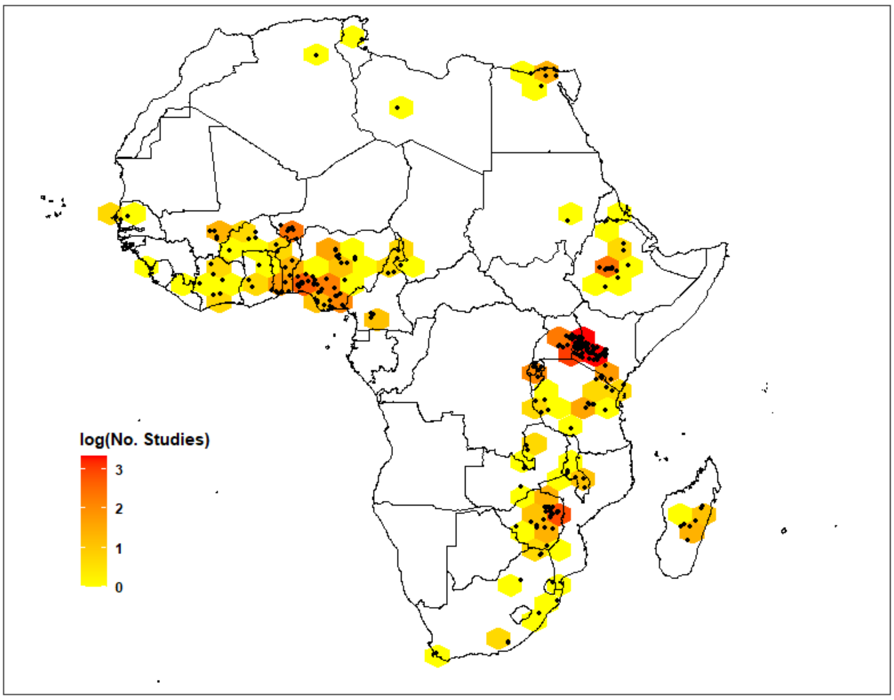


Now what crops do we have Data for

Crops present for Manure-based Organic Fertilizer practices



where Does This Data Come from? we can visualize the spacial distribution of this Data with the ERAHexPlot function



Let's not look at it in term of quantities per country as it looks from this map

Country	
Algeria	1
Benin	38
Burkina Faso	24
Burundi	0
Cameroon	10
Chad	1
Egypt	45
Ethiopia	40
Ghana	10
Ivory Coast	9
Kenya	110
Libya	15
Madagascar	13
Malawi	5
Malawi..Tanzania..Malawi..Nigeria..Kenya	0
Malawi..Tanzania..Malawi..Nigeria..Kenya..Malawi	0
Malawi..Tanzania..Tanzania..Malawi..Nigeria..Kenya..Malawi	0
Mali	9
Niger	68
Nigeria	121
Rwanda	23
Senegal	2
Sierra Leone	0
South Africa	126
Sudan	0
Swaziland	2
Tanzania	22
Tanzania..Tanzania..Kenya	0
Tanzania..Tanzania..Malawi..Nigeria..Kenya..Malawi	0
Togo	11
Tunisia	0
Uganda	60
Zambia	24
Zimbabwe	209

the actual Data we are dealing with Contains 11172 observations with 142 variables. Let's now target the LER from our Subset data (ERA.M).

unique(ERA.M$Out.SubInd)

```
 [1] "Crop Yield"                                 "Gross Return"                               "Soil Nitrogen"
 [4] "Cation Exchange Capacity"                   "Soil Organic Matter"                        "Biomass Yield"
 [7] "Soil Organic Carbon"                        "Water Use Efficiency"                       "Nitrogen Agronomic Efficiency"
[10] "Biodiversity"                               "Infiltration Rate"                          "Gross Margin"
[13] "Soil Carbon Stocks"                         "Nitrogen Use Efficiency (ARE AGB)"          "Phosphorus Use Efficiency (ARE AGB)"
[16] "Nitrogen Use Efficiency (ARE Unspecificed)" "Phosphorus Use Efficiency (ARE Unspecified)" "Soil Organic Carbon (Change)"
[19] "Soil Moisture"                              "Net Return"                                 "Benefit Cost Ratio (NRTC)"
[22] "Return to Labour"                           "Variable Cost"                              "Benefit Cost Ratio (GRVC)"
[25] "Phosphorus Agronomic Efficiency"            "Beneficial Organisms"                       "Nitrous Oxide Emissions"
[28] "Nitrogen Factor Productivity"               "Total Cost"                                 "Erosion"
[31] "Carbon Dioxide Emissions"                   "Labour Cost"                                "Benefit Cost Ratio (NRVC)"
[34] "Marginal Rate of Return"                    "Labour Person Hours"                        "Benefit Cost Ratio (GRTC)"
[37] "Runoff"                                     "Land Equivalent Ratio"                      "Internal Rate of Return"
[40] "Net Present Value"                          "Fixed Cost"                                 "Return on Investment"
[43] "Soil Total Nitrogen"                        "Soil Available Nitrogen"                    "Phosphorus Factor Productivity"
[46] "Soil NH4"                                   "Soil NO3"                                   "Methane Emissions"
[49] "Nitrogen Use Efficiency (ARE Product)"      "Phosphorus Use Efficiency (ARE Product)"    "Potassium Use Efficiency (ARE Product)"
[52] "Potassium Agronomic Efficiency"
```

ERA.M1 <- ERA.M[ERA.M$Out.SubInd == "Land Equivalent Ratio",]

ERA.M1

```
   T11 T12 T13  ID obs_count out_count Lat Lon           yi          pc          plist         base.list EUlist    Out.Pillar Out.SubPillar
1:             832        30         4  NA  NA  0.693147181 100.0000000          b11.2                   c13-h8 Productivity         Yield
2:             832        30         4  NA  NA  0.693147181 100.0000000          b11.2                   c13-h8 Productivity         Yield
3:             832        30         4  NA  NA  0.575364145  77.7777778          b11.2                   c13-h8 Productivity         Yield
4:             832        30         4  NA  NA  0.826678573 128.5714286          b11.2                   c13-h8 Productivity         Yield
5:             832        30         4  NA  NA  0.753771802 112.5000000          b11.2                   c13-h8 Productivity         Yield
6:             832        30         4  NA  NA  0.635988767  88.8888889          b11.2                   c13-h8 Productivity         Yield
7:              54       244         2  NA  NA -0.050430854  -4.9180328            b30           b25-b69 c17-h8 Productivity         Yield
        Out.Ind            Out.SubInd Out.SubInd.S Out.Pillar.Code Out.SubPillar.Code Out.Ind.Code Out.SubInd.Code
1: Product Yield Land Equivalent Ratio          LER     Productivity                 Yi           PY             LER
2: Product Yield Land Equivalent Ratio          LER     Productivity                 Yi           PY             LER
3: Product Yield Land Equivalent Ratio          LER     Productivity                 Yi           PY             LER
4: Product Yield Land Equivalent Ratio          LER     Productivity                 Yi           PY             LER
```

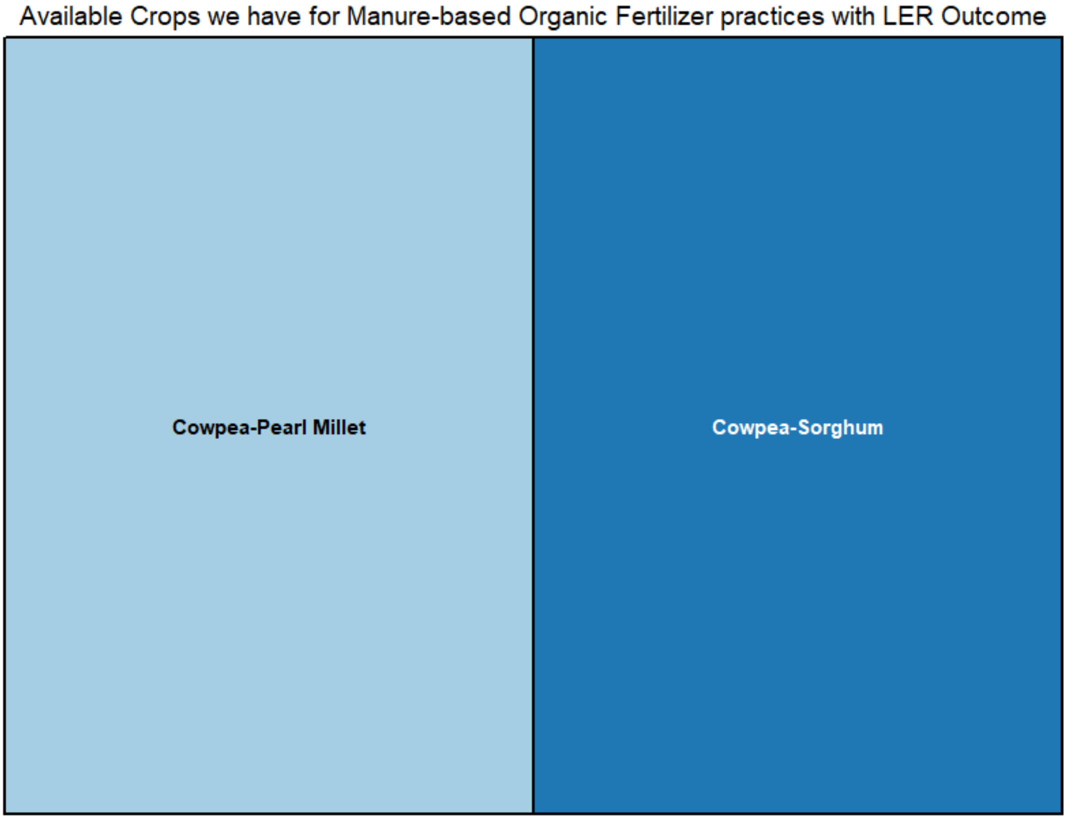
```
ERA.M1            30 obs. of 142 variables
```

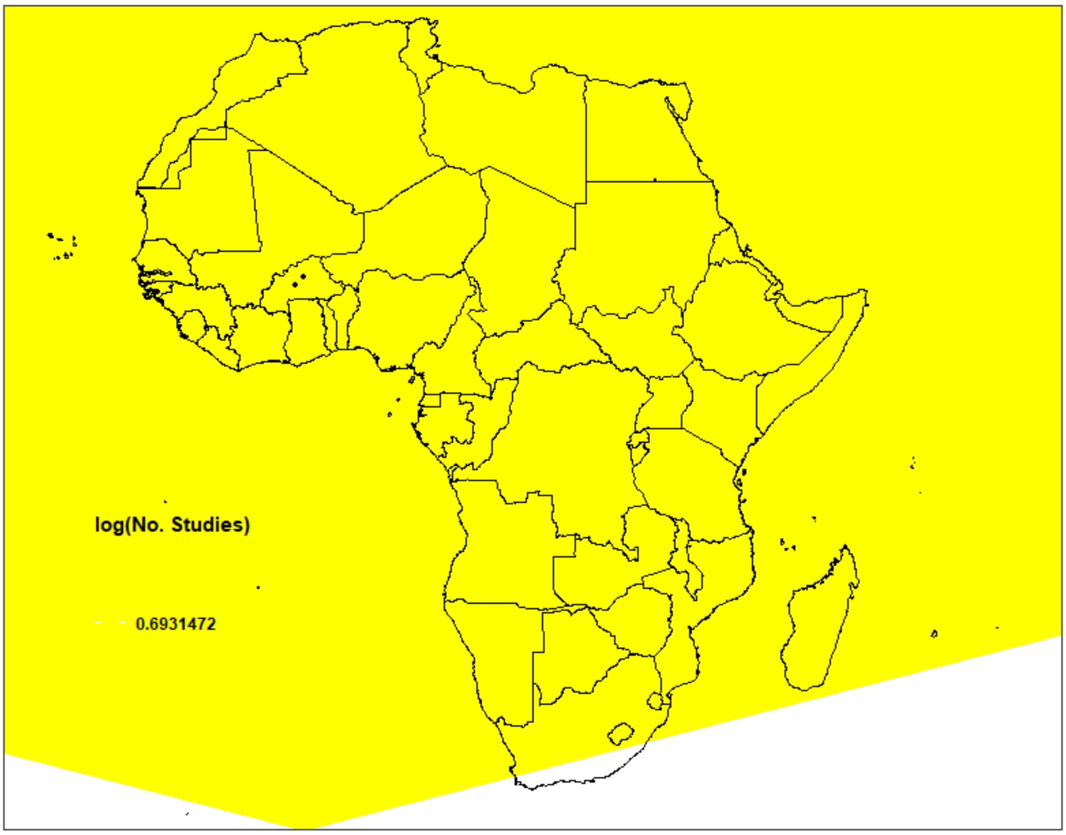
We then have 30 observations of this nature
Before Jumping into the Treemap, we have the following, considering our new Subset

ERA.M2 <-ERA.M1[SubPrName %in% PtPracs]

Let's visualize the available crops for the data we have using the Treemap

ERA.M2.Crops <-ERA.M2[,list(N.Studies=length(unique(Code))),by=list(Product.Simple)]


Available Crops we have for Manure-based Organic Fertilizer practices with LER Outcome
Cowpea-Pearl Millet
Cowpea-Sorghum


log(No. Studies)
0.6931472

7/3/2021

2) The study of individual practices

We have in total 48 unique practices in the practiceCodes data and 344 unique practice Name in the full ERA.Compiled data

```
> length(PracticeCodes[,unique(Practice)])
[1] 48
> length(ERAg::ERA.Compiled[,unique(PrName)])
[1] 344
```

Let's see the new data we get by considering the Outcomes for those unique practices in the full data

```
> EC1 <- ERAg::ERA.Compiled
> EC2 <- EC1[,unique(PrName), Out.SubInd,]
> View(EC2)
```

	Out.SubInd	V1
1	Crop Yield	Inorganic Fertilizer
2	Crop Yield	Crop Residue
3	Crop Yield	Irrigation
4	Crop Yield	Crop Residue Incorporation

…………………………

2180	Potassium Use Efficiency (ARE Product)	Organic Fertilizer
2181	Potassium Use Efficiency (ARE Product)	Inorganic Fertilizer
2182	Potassium Use Efficiency (ARE Product)	Inorganic Fertilizer-Organic Fertilizer
2183	Potassium Agronomic Efficiency	Inorganic Fertilizer
2184	Potassium Agronomic Efficiency	Organic Fertilizer
2185	Potassium Agronomic Efficiency	Inorganic Fertilizer-Organic Fertilizer

the total number of unique outcomes should remain the same 85 in Total. this number being big to display these outcomes on a treemap, let's use a for loop to enumerate these outcomes

```
for (n in EC3) {
  print(paste("the number of Outcome is", nrow(EC2[EC2$Out.SubInd == n , Out.SubInd, V1 ]), "for", n ))
}
```

```
[1] "the number of Outcome is 271 for Crop Yield"
[1] "the number of Outcome is 173 for Biomass Yield"
[1] "the number of Outcome is 101 for Soil Nitrogen"
[1] "the number of Outcome is 157 for Soil Organic Carbon"
[1] "the number of Outcome is 13 for Weight Gain"
[1] "the number of Outcome is 10 for Meat Yield"
[1] "the number of Outcome is 24 for Water Use"
[1] "the number of Outcome is 70 for Water Use Efficiency"
[1] "the number of Outcome is 77 for Soil Moisture"
[1] "the number of Outcome is 4 for Pest & Pathogen (Losses)"
[1] "the number of Outcome is 4 for Pest & Pathogen (Numbers)"
[1] "the number of Outcome is 7 for Feed Conversion Ratio (Out In)"
[1] "the number of Outcome is 88 for Gross Return"
[1] "the number of Outcome is 67 for Variable Cost"
[1] "the number of Outcome is 80 for Gross Margin"
[1] "the number of Outcome is 41 for Soil Organic Matter"
[1] "the number of Outcome is 58 for Cation Exchange Capacity"
[1] "the number of Outcome is 10 for Milk Yield"
[1] "the number of Outcome is 24 for Nitrogen Use Efficiency (ARE AGB)"
[1] "the number of Outcome is 14 for Phosphorus Use Efficiency (ARE AGB)"
[1] "the number of Outcome is 30 for Carbon Dioxide Emissions"
[1] "the number of Outcome is 32 for Erosion"
```

Doing the same thing for practices, we have

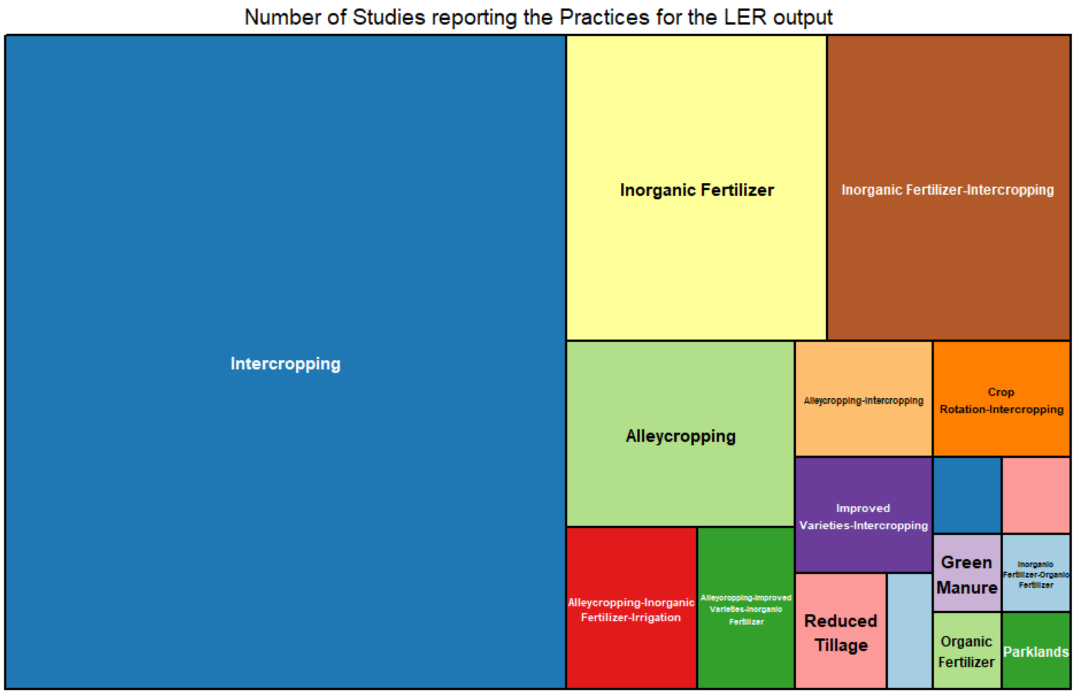
```
for (x in EC4) {
  print(paste("the number of Practices is", nrow(EC2[EC2$V1 == x , Out.SubInd, V1 ]), "for", x ))
}
```

```
[1] "the number of Practices is 56 for Inorganic Fertilizer"
[1] "the number of Practices is 11 for Crop Residue"
[1] "the number of Practices is 22 for Feed Processing-Feed Substitution"
[1] "the number of Practices is 22 for Irrigation"
[1] "the number of Practices is 25 for Feed Addition-Feed Processing"
[1] "the number of Practices is 36 for Crop Residue Incorporation"
[1] "the number of Practices is 31 for Mulch-Reduced Tillage"
[1] "the number of Practices is 37 for Reduced Tillage"
[1] "the number of Practices is 37 for Mulch"
[1] "the number of Practices is 5 for Storage"
[1] "the number of Practices is 48 for Organic Fertilizer"
[1] "the number of Practices is 36 for Inorganic Fertilizer-Organic Fertilizer"
[1] "the number of Practices is 29 for Crop Residue Incorporation-Inorganic Fertilizer"
[1] "the number of Practices is 21 for Improved Varieties"
[1] "the number of Practices is 21 for Improved Varieties-Inorganic Fertilizer"
[1] "the number of Practices is 14 for Feed Processing"
[1] "the number of Practices is 33 for Water Harvesting"
[1] "the number of Practices is 14 for Mulch-Water Harvesting"
[1] "the number of Practices is 6 for Organic Fertilizer-Water Harvesting"
[1] "the number of Practices is 26 for Inorganic Fertilizer-Mulch"
[1] "the number of Practices is 13 for Parklands"
```

For the LER outcomes we have the following practices Names and their numbers in the for Loop

```
> for (y in SS1) {
+   print(paste("-> for", y, "we have", nrow(SS[SS$PrName == y, Code, PrName ]), "in total" ))
+ }
[1] "-> for Agroforestry Pruning-Alleycropping we have 36 in total"
[1] "-> for Alleycropping we have 49 in total"
[1] "-> for Alleycropping-Improved Varieties-Inorganic Fertilizer we have 8 in total"
[1] "-> for Alleycropping-Inorganic Fertilizer-Irrigation we have 10 in total"
[1] "-> for Alleycropping-Inorganic Fertilizer we have 2 in total"
[1] "-> for Intercropping we have 413 in total"
[1] "-> for Inorganic Fertilizer-Intercropping we have 92 in total"
[1] "-> for Inorganic Fertilizer we have 87 in total"
[1] "-> for Improved Varieties-Intercropping we have 23 in total"
[1] "-> for Reduced Tillage we have 4 in total"
[1] "-> for Parklands we have 3 in total"
[1] "-> for Green Manure we have 6 in total"
[1] "-> for Crop Rotation-Intercropping we have 27 in total"
[1] "-> for Agroforestry Pruning-Intercropping we have 16 in total"
[1] "-> for Alleycropping-Intercropping we have 8 in total"
[1] "-> for Organic Fertilizer we have 16 in total"
[1] "-> for Inorganic Fertilizer-Organic Fertilizer we have 8 in total"
```

We can also visualize this with a treemap



3) Let’s look at the **ERA-Large-Climate-Files**

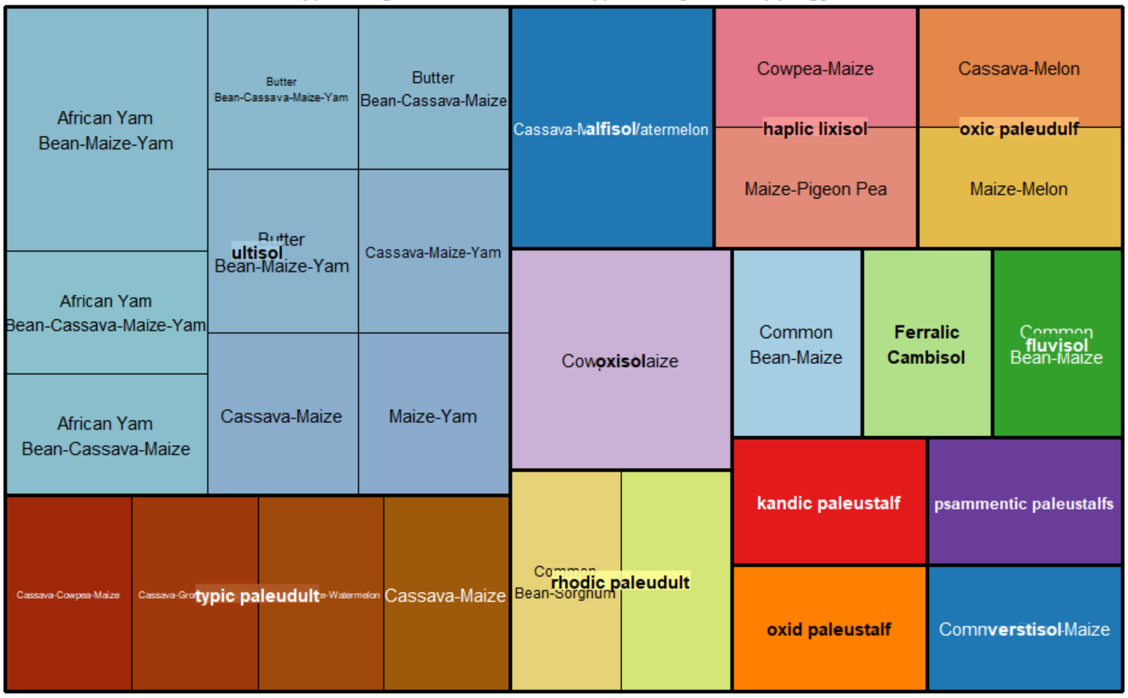
a) Soil type effect on LER

Let study the favorable soil type for our predicted outcomes. We will also use associated practices and products.

Starting with the most outstanding practice "intercropping" to see the soil type we use and what kind of products are resulting. From the following map we can clearly see that the must used soils are

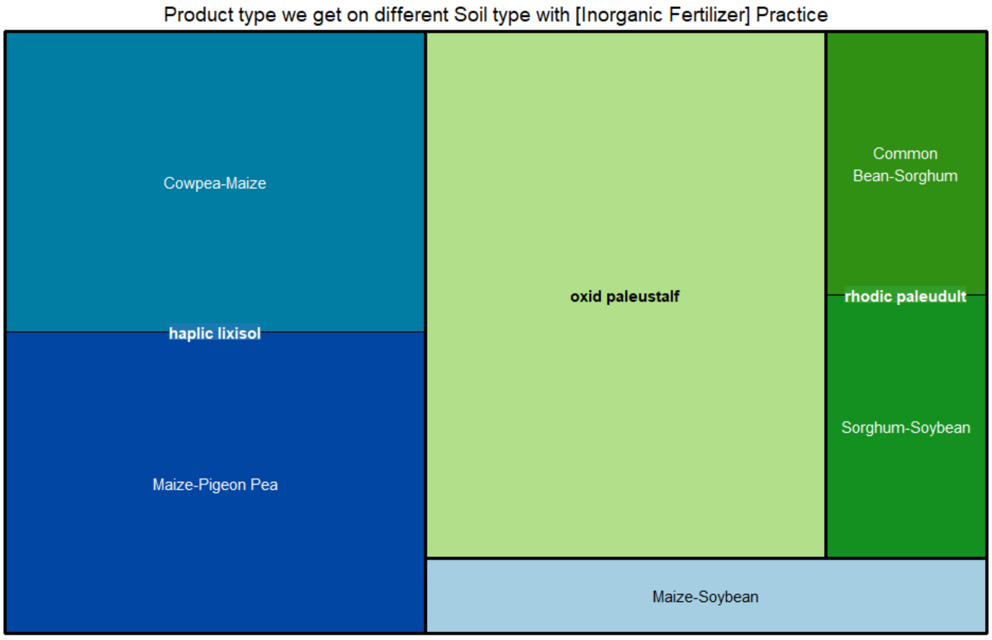
- ultisol
- typic paleudult
- oxisol
- Rhodic paleudult
- alfisol

Product type we get on different Soil type with [Intercropping] Practice

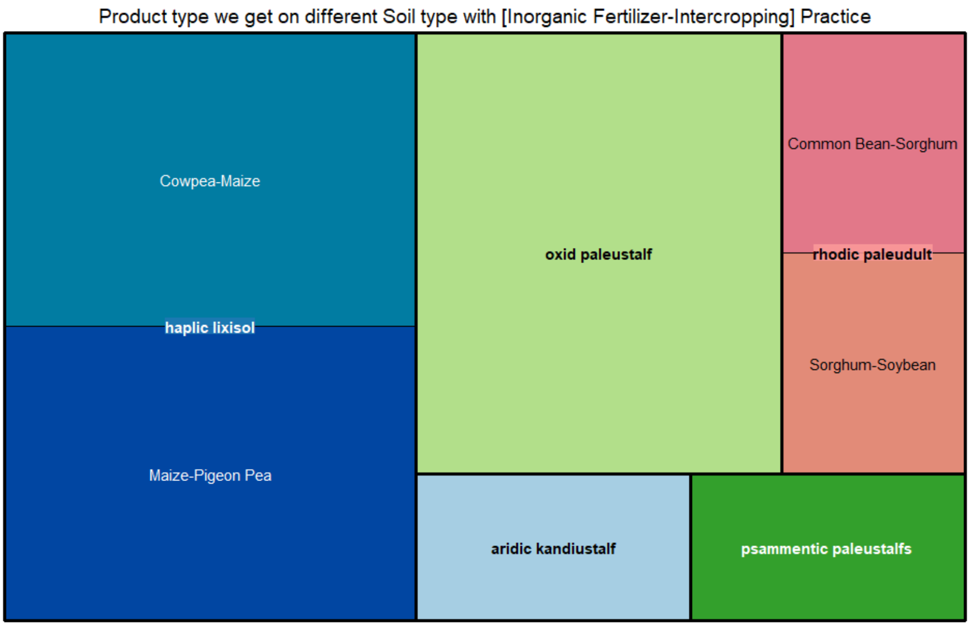


The next most outstanding practice "Inorganic Fertilizer" but therefore, only few soil type are used here

- Haplic lixisol
- Oxid paleustalf
- Rhodic paleudult

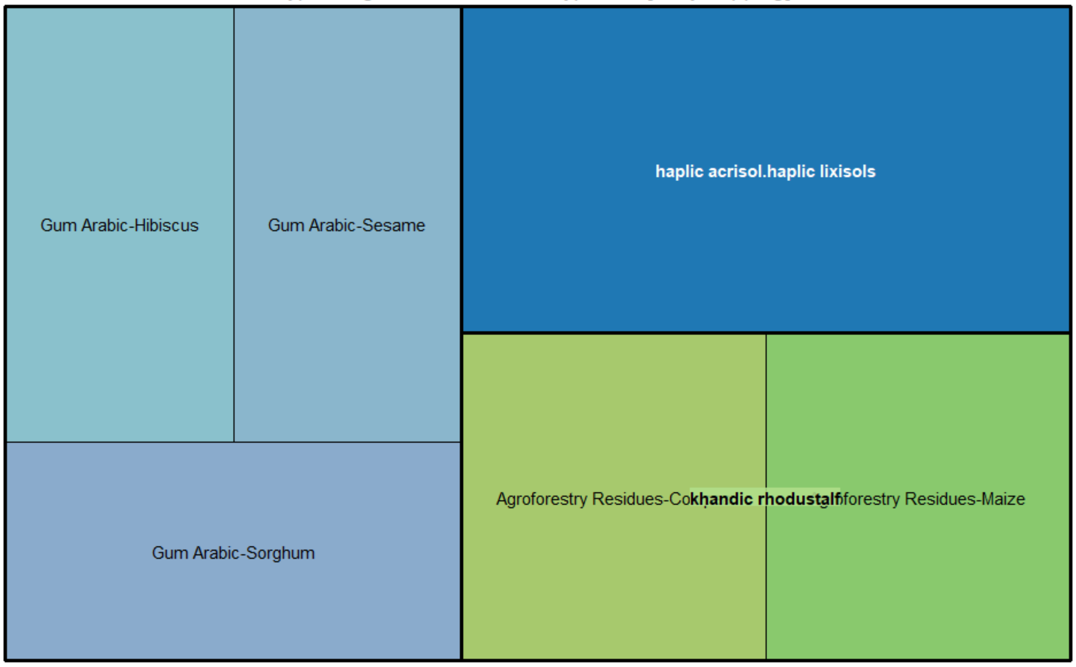


Followed by "inorganic Fertilizer - Inter cropping"



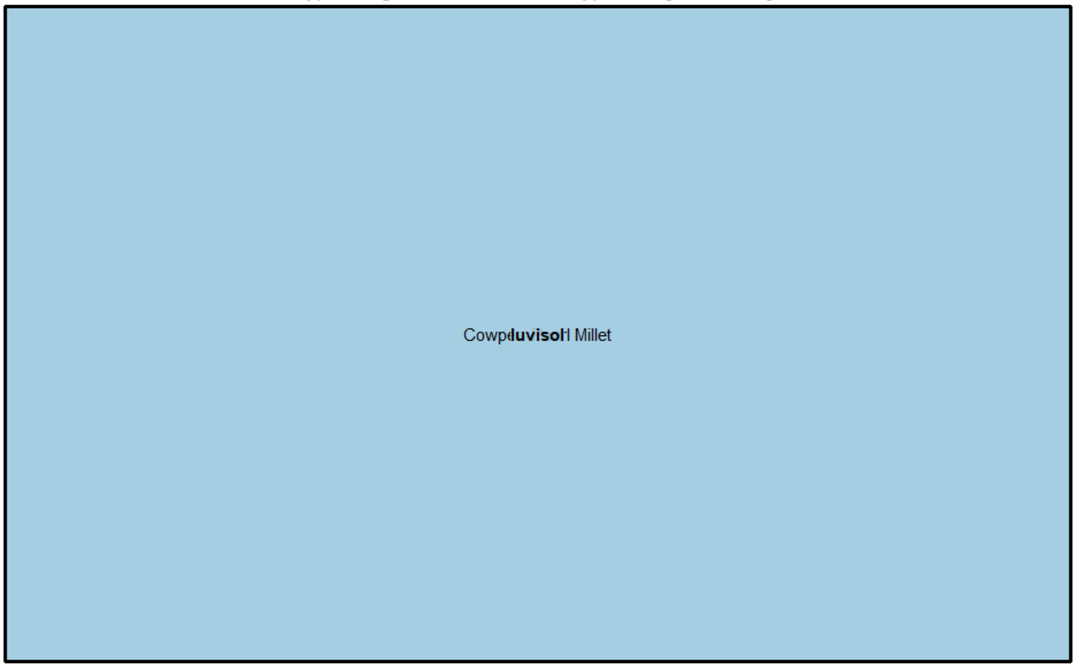
And "Alley cropping"

Product type we get on different Soil type with [Alleycropping] Practice



Finilly the smallest "Parklands"

Product type we get on different Soil type with [Parklands] Practice



What we learn from this is the more various the soil type is the more we have the products which was against my thoughts (For a specific soil type we have a specific product)

b) Soil quality related to Climate a factor