



Proceedings from the Second Regional Workshop on Data Analysis for Tree Volume, Biomass and Carbon Stock Assessment

UN-REDD PROGRAMME

10-13 November, 2014

Peechi, India

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Introduction

Forestry datasets are typically voluminous, hierarchical, messy, multiM faceted, and expensive and have offered a fertile operating environment for data analysts since forest measurements began. Nevertheless, the challenges that forest managers face are complex, and the costs of poor decisions can be high. The 'Regional technical workshop on Tree Volume and Biomass Allometric Equations in South Asia (Kerala Forest Research Institute (KFRI), May 26 M 29, 2014) had concluded that lack of technical expertise in data analysis was a great hindrance in developing accurate tree volume and biomass measurement models. South Asia, with a rich diversity of tree species, has a wide range of datasets and questions in which statistics, econometrics, and applied mathematics tools can all play a constructive role. However the challenge for forest managers is to find the best match between the data, the question, and the tools.

The Regional Training on 'Data Analysis for Tree Volume, Biomass and Carbon Stocks Assessment' during 10-13 November 2014 was conceptualized as a follow up action of the previous workshop to equip forest data managers with the required technical know - how of data analysis. The programme was attended by 21 participants including researchers, foresters and research scholars from Bangladesh, Bhutan, India, Nepal and Sri Lanka (Annex - 1).

The programme started off with a session detailing outputs of the previous workshop wherein gaps and future needs on forest resource assessment in the region were deliberated. Forestry datasets are usually collected and managed according to local or organizational protocols. Datasets may be censored, analyses chaotic, vocabularies inchoate, and processes more often breached than observed. The data analyst must respond flexibly and creatively, document processes, and leave an unambiguous analytical trail. The programme helped the participants to get acquainted with international best practice guidelines on collection, assortment and analysis of forest resources data. The training programme provided a good opportunity for the participants to get a hands-on-experience in R, a free, open source software for statistical computing and graphics. The sessions (Annex - 2) with the details and major R scripts used are explained in the following sections. During the training programme more weight was given to practical use of R scripts.

Session 1: Identification of the gaps and needs

Dr. S. Sandeep

Sandeep S, a scientist from KFRI, presented the outputs of the regional technical workshop on tree allometric equations. The status of the South Asia database, gaps and further needs outlined in the workshop were consolidated and presented before the gathering.

The database had been previously prepared by extensive and exhaustive literature collected from the region by institutional visits, bibliographic databases and FAO reports. Nevertheless, there still remain several lacunae which can be progressively corrected. The database covers a total of 466 documents on tree allometry (Table 1), from which 4456 equations are on volume, biomass, BEF, carbon and other growth variables in South Asia. 375 species belonging to 96 families and 275 genera are included in the database. The proportion of equations contributed to the database by individual nations in South Asia varied as India > Bangladesh> Nepal > Sri Lanka> Pakistan> Bhutan. We couldn't find any tree allometric equation reports from Maldives.

The gaps identified during the previous workshop were

1. Lack of species specific allometric equations

South Asia is a high plant biodiversity area both in number and types of plants. However, a majority of the allometric equations developed in the region were for tree populations. Very few equations are also available for trees outside forests (TOF) and hence their quantification in terms of volume, biomass or carbon stocks poses serious problems.

2. Output parameters

Most available equations focus on tree volume and not necessarily on biomass, and it is not accurate to assess biomass using volume tables or functions. Lack of biomass expansion factors for most species, linked to compounded errors, hampers the prospects of using an alternate method for biomass estimation. Though root biomass is as important as shoot biomass in carbon stock estimations, there were very few studies on roots or their relationship with above ground biomass.

3. Skewed representation of ecological zones

There is high unevenness in the geographical distribution of equations developed across different biomes in South Asia. Most of the allometric equations developed in the region were for tree species in tropical rainforests followed by tropical shrubland. Tropical regimes like tropical moist deciduous forest, tropical dry forest and tropical mountain system were also found to have good number of allometric equations. Tropical desert, subtropical steppe and tropical and subtropical mountain systems with low species diversity have a lower number of allometric equations.

4. Error propagation

Error is the difference between reality and representation of reality. In statistical jargons, it is the absolute difference between observed and estimated values. The statistical error is also called uncertainty. Forest biomass estimation involves measurements using a variety of techniques ranging from simple measuring tape to satellite imageries in a hierarchical fashion. The total error in biomass estimates is the sum of errors in its nested sub components. In biomass estimation, the standard errors of the coefficients of the regression equations (biomass equations) and R^2 are often highlighted as indicators of quality. The studies on actual quantification of error and its propagation through different nested sub components of biomass are scarce. Monte Carlo analysis, Pseudo-meta-analysis and Bayesian model averaging have been suggested as potential techniques in dealing with the issues of error propagation. Among these, Bayesian methods seem to be promising techniques.

5. Data sharing

Though large numbers of tree allometric models have been developed for volume, biomass and carbon stocks estimations in South Asia, their accessibility is very limited as they are mainly confined to scientific articles, and hard copies in institutional or national libraries. Competition between institutions and individuals limits data exchange and transparency. Formal data exchange agreements are missing to allow appropriate collaborations between Research Institutions and national forest inventory holders. Developing standard language and elements of potential data sharing agreements would facilitate the exchange of data

among researchers, potentially increasing the size of existing datasets and allowing for the construction of more robust allometric equations for a larger number of tree species.

6. Lack of technical expertise

New technologies for measuring tree volume and biomass non-destructively are being developed in the region. Though these land-based or airborne remote sensing technologies give information on allometry and decrease the amount of destructive measurements needed, these approaches are expensive for widespread implementation in developing countries, and require capacities that are not readily available.

7. National capacities

Financial, technical, cultural and human capacities may limit data collection, analysis, quality assurance, and sharing of allometric models. Many scientific articles include fees for publication. Not all scientists have the financial capacity to ensure publication of their work and many of the allometric equations are only reported in grey literature making them unavailable to a wider set of audience.

Way forward

Inter institutional and inter regional agreements to share data on tree allometry should be promoted in South Asia under the aegis of lead organizations on tree allometry in the region or international organizations like FAO. In such arrangements it is crucial that data authorship, ownership and use of the data are clarified. Beyond the mechanics of data exchange a change in culture is needed among researchers such that data sharing and collaborations are actively sought. A joint initiative should be build up through frequent technical workshops, capacity building programmes and collaborative projects wherein free exchange of ideas and data will take place. Communication of results and publishing of newly developed methods and allometric equations should be encouraged to promote exchange and positive feedback among the scientific community. Even preliminary results should be shared during scientific meetings to increase the interest of additional developers and potential users.

Introduction to meta-data analysis:

Dr. M. Sivaram

Biomass studies are required to derive carbon and bioenergy estimates. Tree volume and biomass allometric equations have been developed to estimate biomass following non-destructive approach. Recently, the Kerala Forest Research Institute, with the support of the Food and Agricultural Organization has developed a database of tree volume and biomass allometric equations for South Asia. The database contains 4456 equations. However, the applicability and adoptability of the available allometric models and conversion factors to support national forest biomass assessment have not been evaluated. The meta-analysis will allow analysis of the database and provide better guidance to national forest biomass assessment. The motivation of meta-analysis is to achieve a higher statistical power to develop a more correct estimate of effect magnitude rather than just testing the statistical significance. Effect size is a quantitative measure of the strength of a phenomenon such as correlation, regression coefficient, mean difference, relative risk and odds ratio. Meta-

analysis comprises statistical methods for contrasting and combining results from different studies. It analyses the sources of disagreement among the results and highlights interesting relationships and patterns. Meta-analysis is done by identifying a common measure shared between studies like effect size and significance value. The steps involved in undertaking meta-analysis include i) deciding how to search for studies ii) selecting studies based on a set of objective criteria iii) dealing with incomplete data iv) analyzing the data, and v) accounting for or choosing not to account for publication bias. It is clear that if meta-analysis is properly done on the existing tree allometric database for South Asia it will pave the way to know the extent of quality of available equations and their use. It will also help to develop generalized biomass equations for the region.

Session 2: Structure of database

Javier G. P. Gamarra

Javier Garcia Perez demonstrated the structure of database using the one developed for South Asia. The database is composed of 71 variables, grouped in seven categories:

1. Plant ecology (Population and Ecosystem)
2. Geographical location where the equation was developed or applied (Continent, Country, Biomes)
3. Equation parameters (variable characters and ranges)
4. Tree vegetation components (Bark, Root, Stump etc.)
5. Taxonomical description (Family – Genus- Species)
6. Statistical Information (R^2 , adjusted R^2 , bias correction, RMSE and standard error of mean)
7. Bibliographical references

The framework can be used as a common standard for data entry of allometric equations in the region.

Session 3: Introduction to R programming

Maxime Rejou-Mechain, Javier G. P. Gamarra

Basics of R were explained in this session: Installing and using packages, primary R data structures, manipulating data frames, and functions in R with a hands-on exercise with country specific data during the sessions. R can be obtained at <http://cran.r-project.org/>. RStudio basics, also explained, depicted what is a friendly interface to programming in R. RStudio can be installed as a desktop (laptop) application or as a server application that is accessible to others via the Internet. RStudio is available from <http://www.rstudio.org/>

Basic Commands	
Basic Arithmetic	
Addition	+
Subtraction	-
Multiplication	*
Division	/
Exponentiation	^
Other	
Naming objects	=
Open help for a command	?
Creating a set of numbers	c(1, 2, 3)

R at its most basic level is a command-line language, meaning that we interact with R by typing sequences of commands at its prompt. The default prompt, which means that R is ready to receive an instruction, looks like this:

>

Sometimes inputs to R will be longer than one line. In these circumstances, R will change the prompt to let you know that it expects a continuation of a previous input. By default, this is the plus sign:

+

It is also possible to press enter before the line of code is completed, and often R will recognize this. For example, if we were to type 1 + but then press enter before typing 2, R knows that 1+ by itself doesn't make any sense, so prompts for us to continue the line with a + sign. At this point we could continue the line by pressing 2 then enter. This commonly occurs if we forget to close parentheses or brackets. If we keep pressing enter and keep seeing a + sign rather than the regular > prompt that allows us to type new code, and if we can't figure out why, often the easiest option is to simply press ESC, which will get you back to the normal > prompt and allow us to enter a new line of code.

We type commands at the prompt, and if R understands them, then it carries them out and returns the result. For example

```
> 1 + 2
[1] 3
```

The entered code always follows the > prompt, and output always follows a number in square brackets.

There are many different ways to do things in R. There are no official conventions on how the language should be used. Although the equals sign "=" does work for assignment, it is also used for other things, for example in identifying values for arguments. The arrow "<-" is only used for assignment. We use the arrow for assignment, rather than the equals sign. Others use the equals sign. There are four main sources of assistance: the internal help files, the R manuals, the R-help community's archive, and the R-help community itself.

We need to distinguish between the R software application and its packages. When the R application is run, it automatically provides access to a substantial range of functionality. For example, we can compute the mean of a sequence of numbers using the mean function.

```
> mean(c(1, 2, 3))
[1] 2
```

However, still more functions are available to R within packages that are installed by default but not automatically attached to R's search path. To access these packages, we use the library or require functions.

```
> library()
```

Using R effectively virtually demands that we write scripts. We save the scripts to a known directory and then either copy and paste them into the R console or read them in using one of the following commands:

If the R code is not doing what we expect, we often find that it is because the class of the object is not as we expect. We can learn the class of any object by using the class function:

```
> class(mean)
[1] "function"
> class(c(1, 2, 3))
[1] "numeric"
> class(mean(c(1, 2, 3)))
[1] "numeric"
```

creating data frame and its manipulations

The data frame is one of the fundamental data structures within R. For example:

```
> height=c(185,178,165,171,172,76, 200)
> dbh=c(82,81,55,65,68, 3, 30)
> WD = c(454, 678, 443, 234,456, 500, 430)
> Species = c("Euc", "Term", "Pin", "Ced", "Euc", "Ced", "Pin")
> row.names=c("Tree_1","Tree_2","Tree_3","Tree_4","Tree_5","Tree_6","Tree_7")
> result <- data.frame(row.names, Species, dbh, height, WD)
> result
```

	row.names	Species	dbh	height	WD
1	Tree_1	Euc	82	185	454
2	Tree_2	Term	81	178	678
3	Tree_3	Pin	55	165	443
4	Tree_4	Ced	65	171	234
5	Tree_5	Euc	68	172	456
6	Tree_6	Ced	3	76	500
7	Tree_7	Pin	30	200	430

Changing elements

```
> result[2,3] <- 9
> result
```

	Species	dbh	height	WD
Tree_1	Euc	82	185	454
Tree_2	Term	81	9	678
Tree_3	Pin	55	165	443
Tree_4	Ced	65	171	234
Tree_5	Euc	68	172	456
Tree_6	Ced	3	76	500
Tree_7	Pin	30	200	430

```
# Adding new column
> result$new.col <- c(1,38, 54, 79, NA, 4, 89)
> result
```

	Species	dbh	height	WD	new.col	
Tree_1	Euc	82	185	454	1	
Tree_2	Term	81		9	678	38
Tree_3	Pin		55	165	443	54
Tree_4	Ced		65	171	234	79
Tree_5	Euc		68	172	456	NA
Tree_6	Ced		3	76	500	4
Tree_7	Pin		30	200	430	89

```
# Adding new rows
> result[8,] <- c(rep(NA, 5))
> result
```

	Species	dbh	height	WD	new.col	
Tree_1	Euc		82	185	454	1
Tree_2	Term	81		9	678	38
Tree_3	Pin	55		165	443	54
Tree_4	Ced	65		171	234	79
Tree_5	Euc		68	172	456	NA
Tree_6	Ced		3	76	500	4
Tree_7	Pin		30	200	430	89
8	<NA>	NA		NA	NA	NA

```
> rbind(result, new.tree = NA)
```

	Species	dbh	height	WD	new.col		
Tree_1	Euc		82	185	454	1	
Tree_2	Term		81		9	678	38
Tree_3	Pin		55	165	443		54
Tree_4	Ced		65	171	234		79
Tree_5	Euc		68	172	456		NA
Tree_6	Ced		3	76	500		4
Tree_7	Pin		30	200	430		89
8	<NA>	NA		NA	NA		NA
new.tree	<NA>	NA		NA	NA		NA

```
# Calculate mean and standard deviation of dbh
> mean_dbh <- aggregate(dbh~ Species, result, mean, na.rm=TRUE)
> mean_dbh
```

	Species	dbh
1	Ced	34.0
2	Euc	75.0
3	Pin	42.5
4	Term	81.0

```
> SD_dbh <- aggregate(dbh~ Species, result, sd, na.rm=TRUE)
> SD_dbh
```

	Species	dbh
1	Ced	43.840620
2	Euc	9.899495
3	Pin	17.677670
4	Term	NA

Import table

The ability to read and write plain text files is critical because text files are very commonly used for storing and communicating data. Most publicly available growth and yield models use plain text files for input and output, as do many landscape-level database systems and cruise compilers. Furthermore, text files can be straightforwardly managed in version control software (CVS and Subversion) to allow users to track all the changes in data over the lifetime of a project. Text files can be easily transferred through email and FTP programs, and are easily reformatted and displayed in any number of programs. Finally, text files are also in human-readable form, making them ideal for archival purposes.

Unfortunately, text files provide limited flexibility for moving large amounts of data because of the need to convert values into their machine representations, storage and retrieval efficiency, and rounding problems. The additional time required for conversion can be considerable for large datasets.

Table files contain data that is organized in column with an optional header and optional row-names. In this kind of file columns are separated by a specific tabulator (tab-delimited, comma-delimited, etc.) We can load tabular files with the functions `read.table()`. This functions returns data.frame objects.

Text

```
data1 <- read.table(file='/home/user/files/myFile.txt', sep='\t')
```

CSV

```
mydata = read.csv("MyFile.csv")
```

or

```
mydata <- read.table("myFile.csv", header=TRUE, sep=",")
```

Export table

```
write.table(mydata, file = "mydata.csv")
```

Operation on data frame: Creation of new column

```
Eg: > tropicalforest$radium = tropicalforest$dbh/2
> tropicalforest
```

```
> tropicalforest$basal_area = (tropicalforest$radium ^2)*pi
```

```
> tropicalforest
```

Subset of data

Select the 100 first rows

```
> tropicalforest100 <- tropicalforest[1:100,]
```

```

> tropicalforest100

# Select the 100 first rows for the 6 first columns
> tropicalforest100 <- tropicalforest[1:100,1:6]
> tropicalforest100

# Sorting
# Sort the dataframe by a specific column (example: increasing DBH)
> sorted_tropicalforest = tropicalforest[with(tropicalforest, order(dbh)), ]
> sorted_tropicalforest

# Aggregation and calculation within the population
> aggregate(dbh ~ CommercialHeight, data=tropicalforest, FUN = mean)

```

	CommercialHeight	dbh
1	2	20.80000
2	3	29.05000
3	4	41.89706
4	5	51.64706
5	6	70.61111
6	8	83.50000

Session 4: Basic graphics in R

Javier G. P. Gamarra/ Maxime Rejou-Mechain

Session 4 was used to give an overview of graphics in R. Working exercises conducted using available datasets helped the participants to generate high and low level plots in R.

R has a variety of graphics functions. These are generally classed into

- High-level plotting functions that start a new plot
- Low-level plotting functions that add elements to an existing plot

A number of high-level graphics ranging from dotcharts, histograms, boxplots and barplots for one dimensional data, scatterplots for two-dimensional data and contour, image plots and perspective mesh plots for three dimensional data can be produced. Also in the case of lowlevel graphics. These include plotting points, symbols, lines, segments or text on a graph, producing a box around a plot or joining line segments to create a polygon. These types of graphics are often useful for enhancing the feature of an existing plot.

Each function has its own set of arguments. The most common ones are

- xlim,ylim: range of variable plotted on the x and y axis respectively
- pch, col, lty: plotting character, colour and line type
- xlab, ylab: labels of x and y axis respectively
- main, sub: main title and sub-title of graph

General graphing parameters can be set using the par() function.

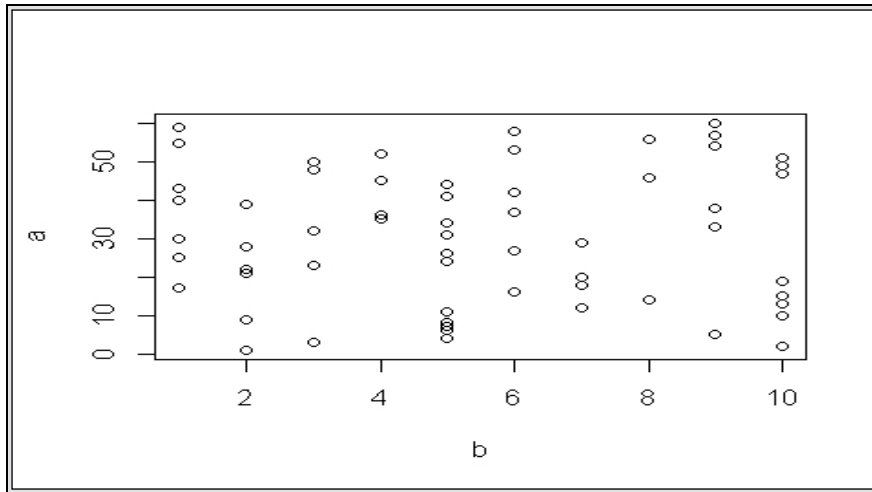
#Graph plots

To create plot (first creating a pseudodataset where numbers from 1 to 10 are sampled 60 times with replacement)

```

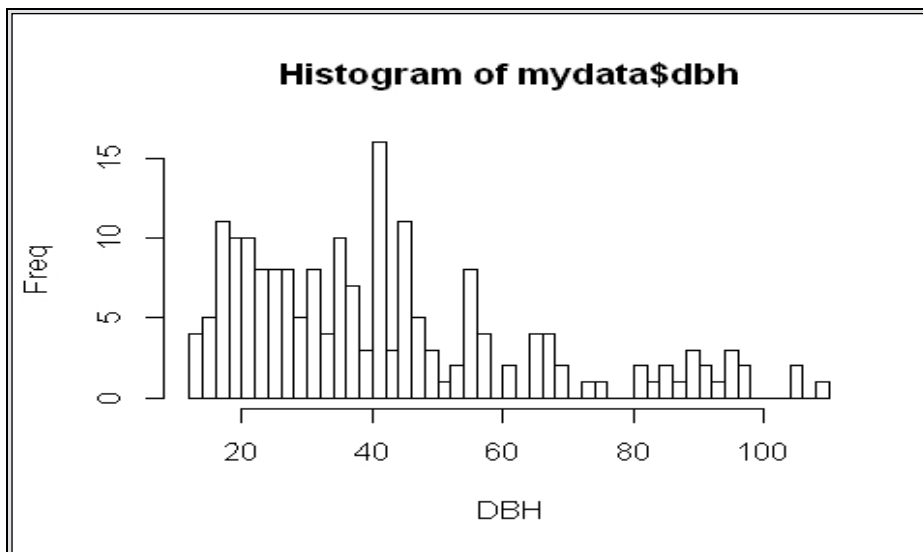
>a<- 1:60
> b<- sample(1:10,60,replace=T)
> plot(a~b)

```



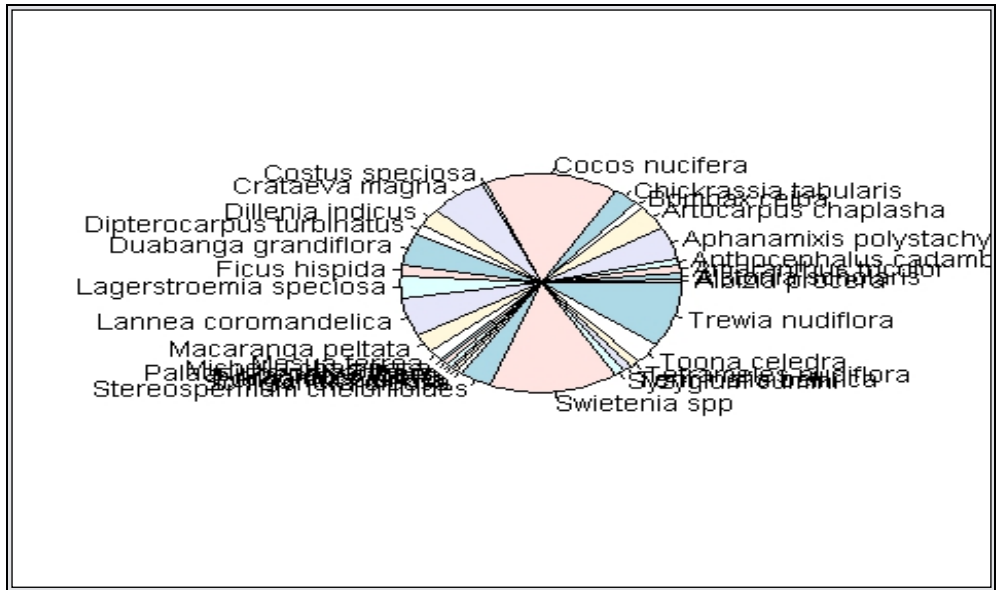
To create a histogram

```
> setwd("C:/Documents and Settings/KFRI/Desktop/KFRIdatasets")
> mydata = read.csv("Plot120_Bang.csv")
> mydata
> hist(mydata$dbh)
> hist(mydata$dbh, breaks = 60, xlab="DBH", ylab="Freq")
```



To create pie diagramme

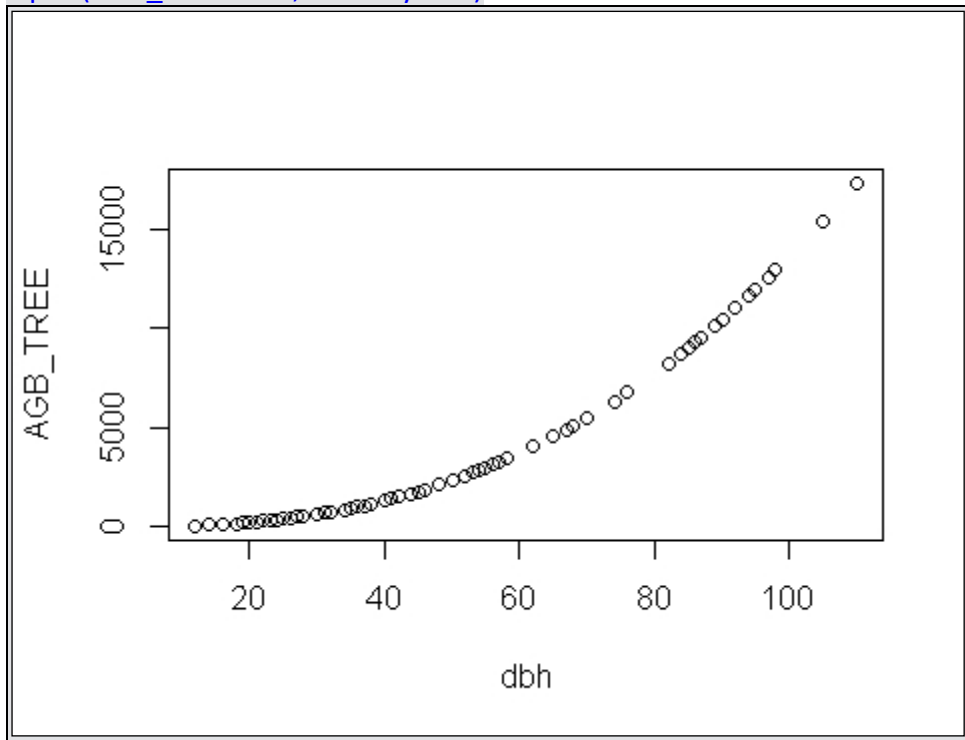
```
> pie(table(mydata$sp), labels=levels(mydata$sp), cex=0.9)
```



```
#Calculate AGB with Brown pantropical equation
```

```
> mydata$AGB_TREE<-exp(-2.134)*mydata$dbh^2.53
```

```
> plot(AGB_TREE~dbh,data=mydata)
```



Session 5,6,& 7: Preparation of data base, Allometric equations and forest resources for one single species, Allometric equations and forest resources for one single plot

Javier Garcia Perez

```
# Setting working directory
```

```
> setwd("C:/Documents and Settings/KFRI/Desktop/rstudio")
```

```
# Importing csv files
```

```
> flora=read.csv("juliflora.csv")
```

```
> flora
```

```
# Getting structure of database
```

```
> str(flora)
```

```
# Getting details of selected equations
```

```
> eqfile<-flora[flora$ID == 12823, ]
```

```
> eqfile
```

```
# Getting column heading
```

```
> flora1 <- flora[flora$espar == "10", ]
```

```
> flora1
```

```
# Getting the details of database(how many rows and columns)
```

```
> dim(flora)
```

```
[1] 24 74
```

```
# Display minimum and maximum values
```

```
> c(eqfile$Min_X,eqfile$Max_X)#original database miniX=3.Here minX=5
```

```
[1] 5 7
```

```
# Minimum values of x
```

```
> xlimmin<-as.numeric(eqfile$Min_X)
```

```
> xlimmin
```

```
[1] 5
```

```
Getting maximum values of x
```

```
> xlimmax<-as.numeric(eqfile$Max_X)
```

```
> xlimmax
```

```
[1] 7
```



```

# Give the values of X (with increment 0.5)
> xseq<-seq(xlimmin,xlimmax,0.5)
> xseq

[1] 5.0 5.5 6.0 6.5 7.0

# To show all the equations
> eqfile$Equation
[1] (-0.3525)+1.3972*X
24 Levels: (-0.0255)+0.3122*X (-0.0565)+0.7069*X (-0.0688)+0.0083*X ...
0.1292+0.5924*X^(2)*Z

# Substitute values of x
> x<-xseq
> evaleq<-function(eq)eval(parse(text=eq))
> eval(parse(text=eqfile$Equation))
[1] 6.6335 7.3321 8.0307 8.7293 9.4279

# To show maximum values of y
> ylimmax<-max(sapply(eqfile$Equation,FUN=evaleq))
> ylimmax
[1] 9.4279

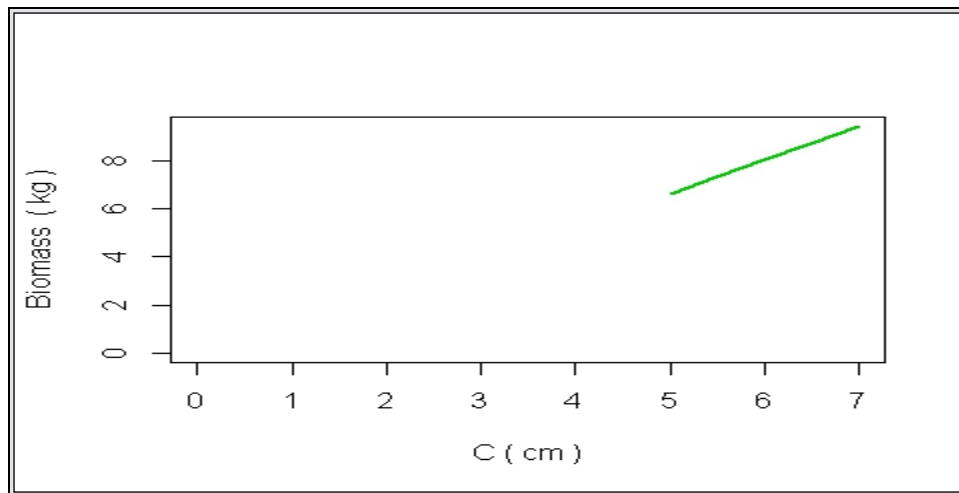
# To show the unit of x
> xlab<-paste(eqfile$X,"(",eqfile$Unit_X,")")
> xlab
[1] "C ( cm )"

# To show the unit of y
> ylab<-paste(eqfile$Output,"(",eqfile$Unit_Y,")")
> ylab
[1] "Biomass ( kg )"

# Combinatin of x and y
> c(xlab,ylab)
[1] "C ( cm )" "Biomass ( kg )"

# To draw line diagraeme
lines(x,eval(parse(text=eqfile$Equation)),lwd=2,col=3)

```



Summary and Conclusions

The training Programme gave an opportunity to researchers and foresters in the region to get acquainted with the basics in R. The sessions in R were arranged in the order:

1. Introductory session with R
2. Graphics in R
3. Preparation of data base
4. Estimating biomass from allometric equations and forest resources for one single species and
5. Estimating biomass from allometric equations and forest resources for one single plot

The hands on exercises helped them to evaluate their own databases. Capacity building is an essential part to create efficient and skilled manpower on tree allometry in the region. New methods to assess forest biomass have a strong technological component. Transfer of knowledge should be considered a key point for improving biomass estimation as the biological and statistical concepts are difficult to understand. Countries should be supported in developing these capacity needs and to develop plans to cover all important areas of the forest inventory. The programme concluded that efforts to advance the knowledge in statistical analytical tools should be taken and a further training on modeling (Linear and Non-linear Modeling) techniques using R should be conducted in the near future.

Annex -1: List of participants

	Participant name	Email ID	Designation
Bangladesh			
1	Mr. Nirmal Kumar Paul	paulnirmalbgd@hotmail.com	Divisional Forest Officer, Management Plan Division, Khulna
Bhutan			
2	Dr. Purna Chettri	purnab_2000@yahoo.com	RDC, Bhutan
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Sri Lanka			
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Annex - 2 : Programme Schedule

10 th November			
Time	Topic	Speakers	MC/Facilitator
8:00-9:00	Registration		
Inaugural Session			
9:00	Welcome speech		Director (KFRI)
	Inaugural speech		Javier Garcia (FOM)
9:30	Objectives of the training		Dr. Sivaram
Session 1			
Identification of the gaps and needs			
10:15	Summary of the outputs of the regional technical workshop on tree allometric equations for South-Asia	Dr. S. Sandeep	
10:45	Introduction to meta-data analysis	Dr. M. Sivaram	
11:00	Group discussion		
Session 2			
Structure of databases			
11:15	Course	Javier Garcia Perez	
12:00	Exercise	Javier/Sandeep/Sivaram/Maxime	
Session 3			
Introduction to R programming			
15:00	Course	Maxime Rejou-Mechain /Javier	
16:00	Exercise	Javier/Sandeep/Sivaram/Maxime	
11 th November			
Introduction to R programming contd..			
9:00	Course	Javier GarciaPerez /Maxime	
10:30	Exercise	Javier/Sandeep/Sivaram/Maxime	
Session 4			
Basic graphics in R			
14:00	Course	Javier/Maxime	
15:30	Exercise	Javier/ Sandeep/ Sivaram/Maxime	
12 th November			
Session 5			
Preparing databases			
9:00	Course	Javier Garcia Perez	
10:30	Exercise	Javier/Sandeep/Sivaram/Maxime	
Session 6			
Allometric equations and forest resources for one single plot			
14:00	Course	Javier GarciaPerez	
15:30	Exercise	Javier/Sandeep/Sivaram/Maxi	

		me	
13 th November			
Session 7	Allometric equations and forest resources for one single species		
9:00	Course	Javier GarciaPerez	
10:30	Exercise	Javier/Sandeep/Sivaram/Maxime	
Valedictory session			
14:00	Feedback and closing remarks	All participants/ Javier/Sandeep	Director (KFRI)

