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Al-Quds University

Developing Local Mathematical Equations For Estimation Above Ground Biomass of Date Palm *(Phoenix dactylifera*) Tree Using Field Measurement in Jordan Valley Region

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M.Sc. Thesis

Jerusalem-Palestine

1442/2021

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A Thesis Submitted in Partial Fulfillment of Requirements for the Degree of Master Agricultural extension, Institute for Sustainable Development, Faculty of Graduated Studies -Al-Quds University

Al-Quds University

Deanship of Graduate Studies

Institute for Sustainable Development

Thesis Approval

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Master thesis submitted and accepted, Date: 24 / May / 2021

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Jerusalem-Palestine
1442/ 2021

Dedication

I dedicate this work to my family and friends, a special of gratitude to my loving parents whose words of encouragement and push for tenacity ring in my ears, and my wonderful brothers and sisters who never left my side all along the journey .

Ruban Abu-Alrub

Declaration

I certify that this thesis submitted for the degree of Master in Institute for Sustainable Development is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not be submitted for a higher degree to any other university or institution.

Ruban Abu Alrub

Signature:

Date : 24/ May/ 2021

Acknowledgment

With many thanks to my supervisor Prof. Amir Marie for his consistent support and guidance during the running of this research, and I would like to thank the Ministry of Agriculture represented by The Jericho Station for Agricultural Research for allowing me to research in their Date Palm fields.

Furthermore, I am deeply grateful to the Union of Agricultural Work Committees for their support in funding my scholarship, as well as, my sincere thanks and respect to Al-Quds University.

Abstract

The cultivation of Date Palms in the Jordan Valley region is a key for development in such arid regions, it has a high adaptation to drought and salinity conditions there, in recent years, the Jericho region has recorded a great spread in the planting area of Date Palm cultivation as a high-value fruit crop until it has become the most important branch for the agricultural sector in the region. Given that the quantitative evaluation of any resource is the first step in its management towards achieving sustainability. This study focused on Above Ground Biomass (AGB) as an effective tool for an environmental assessment, for the Jordan Valley region, any vegetation cover there, could be considered to be a sensitive indicator for climate change adaptation, accordingly the assessment of Date Palm biomass is useful in predicting the carbon sequestered in these arid ecosystems, as it is the most prevalent plant in addition to the possibility of monitoring climate change through the response of date palm trees.

This thesis aims to develop a local equation for estimation AGB, by the structural parameters of Date Palm tree, to achieve the research aims field data were collected for three common varieties of JSAR within different age groups, the collected data was analyzed by using the Excel package and SPSS software.

The results indicate that crown area (CA) is the best field parameter for estimating AGB of Date Palm trees at medium age by a function of crown biomass variable, while the height of trunk is the best field parameter for estimating AGB of mature Date Palm trees by a function of trunk biomass variable, each model has specific equations to use.

Accordingly, the study came out with a set of recommendations, the most important of which is to adopt these equations as local models for estimation AGB and encourage research to develop them for higher accuracy, in addition to using remote sensing techniques in the measurement method.

تطوير معادلات رياضية محلية لتقدير الكتلة الحيوية لأشجار نخيل التمر باستخدام القياس الحقلي في منطقة وادي الاردن

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الملخص

تعتبر زراعة نخيل التمر في منطقة غور الأردن مفتاحًا لتنمية مثل هذه المناطق القاحلة ، نظرا لتكيفها العالي مع ظروف الجفاف والملوحة فيها ، حيث سجلت منطقة أريحا في السنوات الأخيرة انتشارًا كبيرًا في المساحات المزروعة بأشجار نخيل التمر ، كمحصول فاكهة عالي القيمة حتى أصبح أهم فرع للقطاع الزراعي في المنطقة.

وبالنظر إلى أن التقييم الكمي لأي مورد هو الخطوة الأولى في إدارته نحو تحقيق الاستدامة، ركزت هذه الدراسة على الكتلة الحيوية فوق الأرض (AGB) كأداة فعالة للتقييم البيئي، فبالنسبة لمنطقة وادي الأردن، أي غطاء نباتي فيها يمكن اعتباره مؤشرًا حساسًا للتكيف مع تغير المناخ ، وبالتالي فإن تقييم الكتلة الحيوية لأشجار نخيل التمر مفيد في التنبؤ بالكربون المحتجز في هذه النظم البيئية القاحلة باعتبارها النبات الأكثر انتشاراً فيها، بالإضافة الى امكانية مراقبة التغير المناخي من خلال استجابة أشجار نخيل التمر.

تهدف هذه الأطروحة إلى تطوير معادلة محلية لتقدير الكتلة الحيوية فوق سطح الأرض من خلال المعلمات الهيكلية لشجرة نخيل التمر، لتحقيق أهداف البحث ، تم جمع البيانات الميدانية لثلاث أصناف من أشجار نخيل التمر الشائعة في المنطقة من محطة أريحا للبحوث الزراعية ضمن فئات عمرية المختلفة ، وتم تحليل البيانات التي تم جمعها باستخدام حزمة Excel وبرنامج SPSS.

تشير نتائج الدراسة إلى أن مساحة التاج هي أفضل معلمة ميدانية لتقدير الكتلة الحيوية فوق سطح الأرض لأشجار نخيل التمر متوسطة العمر بدالة متغير الكتلة الحيوية التاجية ، بينما وجد ان ارتفاع الساق هو أفضل معلمة ميدانية لتقدير الكتلة الحيوية فوق سطح الأرض لأشجار نخيل التمر الناضجة بدالة متغير الكتلة الحيوية الجذعية ، حيث ان كل النموذج لديه معادلة محددة لاستخدامها.

وعليه خرجت الدراسة بجملة من التوصيات أهمها اعتماد هذه المعادلات كنماذج محلية للتقدير الكتلة الحيوية فوق سطح الأرض وتشجيع الأبحاث التي تجمع بين القياس الحقلي باعتماد النماذج المُحدثة و تقنيات الاستشعار عن بعد في تقدير الكتلة الحيوية فوق سطح الأرض للحصول على مزيد من الدقة في النتائج.

LIST OF ABBREVIATIONS

AGB	Above ground biomass
BGB	Below ground biomass
CB	Crown biomass
TB	Trunk Biomass
DBH	Diameter at breast height
CA	Crown Area
CD	Crown Diameter
Cd	Crown depth
H	Total Height
Ht	Trunk Height
#No. Fronds	Number of Fronds
C.R	Calculated Result
A.C	Actually Result
JSAR	The Jericho Station for Agricultural Research
FAO	The Food and Agriculture Organization

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Chapter. 1

1.1 Introduction

The agricultural sector is the main base of the Palestinian economy, where agricultural activities reactivate multiple industries through their inputs and outputs, under the challenges imposed by the Israeli occupation on this sector, its contribution to the GDP has decreased, as (UNTKAD,2015) reported a marked decrease in the index between (1987-2011) from (18.8 - 5.6) respectively until reaching 3.1 by 2018 (MAS, 2018).

However, these statistical data can't reflect the importance of the agricultural sector to the Palestinian people, as there is a close relationship between land and agriculture with the Palestinians over the past years which remained until now and we can observe that in our culture and our social lifestyles, where women contribute 33% of the total workforce (PSI, 2019), in addition to the role of agriculture in promote rural development, and most importantly, it being the first line of defense for the Palestinian issue.

Moreover, this effect is not limited to the decline in the value of the agricultural sector just, indeed there is a clear change happened in agricultural patterns, especially in the Jordan Valley region, when we tracked the agricultural data it was noted the shift of farmers from cultivating vegetables and bananas to the fruit crop cultivation as the Date Palm tree (Social Economic Polices Monitor,2020)

Date Palm *(Phoenix dactylifera L.)* is an important crop plant were amongst the first crops domesticated (Rabei.S, Said.W, 2012), most studies indicate that the original place was Mesopotamia while the authors altogether confirm that it found early in the world to the period 4000 B.C (Taheri.M, 2016). Whereas in the early 2nd millennium B.C a famous investiture scene to Date Palm has been depicted on the southern wall of one of the main courtyards in the palace of Mari in Syria (Tengberg.M, 2012). While (Chich.T, Robert.R, 2007) pointed that date culture had spread into Egypt by the middle of that period, this indicates that mean it early entered the region of Palestine may be at that time too.

The global demand for date palm is increasing due to its entry into the multi food industry, in the same time the Arab motherland provides about 74.5% of the global total production (Alshurfa.M , 2018), whereas palm cultivation is widespread in arid n Mediterranean regions, due to the high adaptation of these species to the hot climatic conditions and lack of water in these areas.

As for the Palestinian region, cultivation has spread in the Jordan Valley, where there are optimal conditions, in the same time (Sonneveld.B, et al, 2018) predicted the possibility of palm tree expansion in Jericho to reach about 30000 dunum by the year 2023, where he assured that Jericho's more suitability for cultivating this variety than other as it ranked first in the West Bank according to a Liebig test which applies a rule-based procedure (FAO). With regard to common cultivars (Abu-Qaoud.H ,2015 and Ighbareyeh.J, et al, 2015) pointed that a high-quality date palm cultivar (Medjool) was entered by _Israeli farmers after 1967_ , then the Palestinian farmers adopted it and developed the techniques were used to improve the yield and quality of the product to meet consumer needs, also, to increase the Competitive in the local and international market.

The historical reading of data received from the Ministry of Agriculture related to the cultivated area and production in the study area indicates that we can divide the sector growth into two phases (2005 -2012) and (2013-2019), the second stage is distinguished than the first phase with a steady increase in agricultural areas at a rate of 1850 dunum annually and doubling the production rates by 1300 tons annually. This was previously pointed by (Sonneveld.B, 2018) that date palm has been an export commodity since 2005.

As for the period between (2005 – 2012), the average cultivating area was expanding at the rate of 1300 dunum annually, while productivity rates were low at a rate of 300 tons. This can be explained by the start of the production of palm trees after four years of cultivation (when the tree reaches maturity), in addition to the excesses of occupation on farms, as stated in the report (Unktad, 2015) that uprooting 34,000 palm trees until 2013.

The rapid increase in the demand for date palm products in both internal and external markets, caused an expansion in the cultivated areas while the palm trees became an important economic branch in the Jordan Valley region, in addition to that the high adaptation of palm tree with this arid region, which contributed to the investment growth in this region, however, some challenges threaten the sustainability of the palm sector in the long term, which will negatively affect the economies of the region

Wherese, the natural resources in the region are exposed to more pressure as it suffers from a scarcity of fresh water and drought of wells, where (Abugesh.A,2018) in his study of the determinants of expansion in palm cultivation, he stated that 79.4% belong to determining water and land together, and the land is meant here soil in terms of its properties.

Whereas the economic feasibility study in the special circumstances of the study area is no longer sufficient to guide investment and the development of palm projects, where he stressed (Schaffers.A ,2001) that water and soil nutrient deficiency is a major factor limiting productivity while (Djibril.S, et al, 2005) said drought and salinity affect the amino acid (proline) content in date palm seedlings which identify the general response to any stress in the plant, in addition to some agro- practices that include saline water irrigation and overusing of chemical fertilizer, which will affect the soil properties in the long term, particularly that arid and semi-arid regions considered as more sensitive to climate changes in the region, this leads to that the growth of date palm trees influenced by these factors. In fact (Tripler. E, et al, 2011) observed a reduction in vegetative growth for three date palm varieties in the southern Arava region as a response to salinity, that means the canopy area which bears dates clusters will be influenced, affecting the profitability of the farmers, as well as the economics of the sector in general due to the value export of this product.

Furthermore (AlKharusi.L, et al, 2017) pointed that global annual losses in agricultural crops due to salinization add up to more than US $12 billion, which means more environmental pressure, which limits the ideal growth of date palm trees. Accordingly, it is not sufficient to study the economic feasibility just when deciding to expand in agriculture and investment.

Accordingly, it is recommended to look for the environmental role of Date Palm planting by estimating the quantitative growth (AGB) by using specific mathematical equations, then it can reflect the carbon storage in the region.

1.2 Problem Statement

Above-ground biomass is an effective tool for an environmental estimation and as a defining factor for productivity, despite serious studies that have been presented to estimate AGB in this region, but is limited to herbs and shrubs, therefore Date Palm tree should take into consideration in conjunction with the rapid increase in cultivation area in Jordan Valley Region by developing a local model for estimation AGB, due it's an effective tool for monitoring both of climate change and economic changes, in addition, it reflects the health of the plant. In this context, our study focuses on developing a local mathematical equation to assess the AGB, the presence of such an equation which depends on AGB helps in achieving sound practices that ensure better growth for date palm canopy and higher productivity, which achieve sustainability of this important agricultural economic branch in the sector, in addition, the possibility of monitoring the climate change in this sensitive area.

1.3 Study Justifications

- Most of current the studies focus on the date palm economic feasibility (financial evaluation) and the obstacles for expansion, without giving attention to find evaluation environmental tool for this resource, which help decision-makers to manage this sector sustainably.
- The lack of information about the relationship of Date Palm biomass to productivity and analysis of factors associated with it.

- Since the Jordan valley has the saltiest groundwater in the area, besides, to raise an average of evaporation, it shown an urgent need to understand the interrelationship between growth environment and date palm biomass and the extent of its impact on the yield.

- The need for a database as a reference for expansion plans investment in agriculture sector particularly in date palm plantation scope, through this study we can get to the agriculture models used to support decisions regarding the daily management of farms, and which applied in making operational, tactical and strategic decisions regarding for expansion plans in agriculture and investment in date palm sector.

1.4 Aims and objectives

The major aim of this study is to develop a new local mathematical equation for estimation AGB.

To achieve the main aim of this study a set of specific objectives has been assigned as follow:

1. Collect the above ground biomass data of three Date Palm varieties using field measurement
2. Estimating (AGB) for the varieties and find which variety has the most ability in AGB accumulation
3. Study the relationship between the estimated AGB and the structural parameters of the Date Palm tree and developing specific local equations for assessing AGB.

1.5 Hypotheses of Study

The main hypothesis refers to there is no statistically significant relationship at the level of significance ($\alpha<0.05$) between Date Palm biomass and the structure parameters of tree.

1.6 The question of the Study

What is the relationship between Date Palm biomass and the structure parameters of tree?

1.7 Study model

Independent variable: The structural descriptors of Date Palm tree

Dependent variable: Date Palm Biomass

Research Plan

Chapter 1: Study problem, justifications, importance, objectives, questions, hypotheses, model & plan.

Chapter 2: Literature review & Comments on the previous studies.

Chapter 3: Materials & Methods.

Chapter 4 : Result & Decisions.

Chapter 5 : Conclusions & Recommendations.

Chapter. 2
Literature Review

2.1 Background

One of the biggest important issue in the world is moving towards a green economy to reduce the global emissions by limit fossil fuels utilization, in the same time the deforestation of the forest is a main challenges. For this reason a lot of research focused on how to manage the ecosystems and monitor the generally changes through estimating plants biomass, considering it as a sensitive indicator to predicting of ecological performance and observing environmental changes, according to FAO, 2004 biomass is defined as the total amount of live and inert organic matter above and below ground expressed in tons of dry matter per unit area. Darke.J, et al, 2003 is one of the pioneers in defining the term of plant biomass as the weight of living plant material contained above and below a unit of ground surface area at a given point in time, likewise Vazirabad.Y and Karslioglu.M, 2011 , Rodriyuez.A , 2017 define the above ground biomass as the oven-dry mass of the above ground portion of a group of trees in forestry, while Ravindranath.N, et al, 2008 defined below-ground biomass as the entire biomass of all live roots, as a result that there is no standardized system to distinguish the live and dead roots, below ground root biomass is reported as total of live and dead roots. However there are a few studies about below ground biomass estimation (Vazirabad.Y and Karslioglu.M, 2011), which was limited for grassland systems to develop simple models to estimate missing components of total net primary production from system (GILL.R, et al, 2002), and it's also measurement as sub-form in a study of Næsset.E ,2008 and Koala.J et al, 2017 to develop models for estimation the carbon stored in forests in West African north Sudanian zone, on the other hand the estimating of above ground biomass have been found a great interest from authors and this may attributed to the measurement simplicity and the possibility of using regular method to measure the AGB was the interest of researchers and developing new method, the rapid development of remote sensing techniques which contributed to estimate above ground biomass effectively in wide scale for trees, shrubs, herbs and pastures in different type ecosystems.

2.2 Measuring Biomass in different ecosystem

Silva.F et al, 2015 and Jaramillo.V, et al, 2018 and Vorster.A, et al, 2020, studies claimed that tropical forest ecosystem got more attention in above ground biomass estimation, because of the majority role of this ecosystem in carbon cycle as stocks and sinks, Saatchi.S et al, 2011 confirmed that it store 70–90% of the terrestrial carbon. Furthermore Vashum.K, 2012 reported that the estimation of the accumulated biomass in the forest ecosystem is important for assessing the productivity and sustainability in addition to the accurate assessments important for many applications like timber extraction and tracking changes in the carbon stocks of forest and global carbon cycle, in this context .

As for the arid and semi-arid regions Ubuy.M, et al, 2018 observed that there are a few models for estimation of biomass that are developed despite large areas which are covered in the world, this may back to the dispersed distribution of the vegetation cover growth. Suganuma.H, et al, 2006 stated that in recent years serious studies presented to estimate AGB in an arid and semi-arid region in conjunction with the increasing concerns about the global climate, furthermore these areas are more sensitive to climate change, for this reason, great efforts were invested in developing specific models for estimating above ground biomass which shown in literature

(Ubuy.M et al, 2018, Svoray.T and Shoshani.M, 2002, Wang.G et al, 2018, Issa.S et al, 2018, Chen.W et al, 2018 and Cienciala.E et al, 2013).

2.3 **Developing of Biomass Measurement Method**

In general, the previous studies have been shown many different methods to estimate AGB, which we can summarize in field measurement, remote sensing, and GIS methods, and in a majority of studies two measurement methods have been combined to achieve result accurately (Holopainen.M, et al, 2011 and Issa.S, et al, 2020 and Bernasconi.L, et al, 2017 and Svory.T, 2002 and Suganuma.H , et al, 2006), in this context, the field measurement is the traditional method for estimating AGB which is given in two approaches, the first one is the destructive method of biomass estimation, which Poudel.K and Temesgen.H, 2016, Eisfelde.C, 2016 notified that it can be used for a sample plots population which selected randomly and harvest all trees in that plot then measuring the weight of the different components of the harvested tree like the tree trunk, leaves and branches and measuring the weight of these components after they are oven-dried, In the same time Vashuam.K, 2018 described this approach with harvest method term, therefore it is complicated, labor-intensive, expensive and time-consuming, in addition to that Montes.N et al, 2000 in his study of estimating the biomass of a juniper woodland *(Juniperus thurifera L.)* found in the High Central Atlas mountains (Morocco) that this method is not well suited to the natural environment, especially if it is subject to degradation or containing threatened species, both Na´var.J, 2009 and Daba.D et al, 2019 used the destructive method for developing biomass equation for specific species plant to be applied on a large-scale.

The second method in the field measurement approach is the non-destructive method where Vashum. K, 2012 recommended applying this method for ecosystems with rare or protected tree species where harvesting of such species is not very practical or feasible. de Gier , 2003 and Adhikari.M , 2015 preferred the non-destructive method (which relay on talking sub-samples from the tree (wood or leaves)) over the destructive method, they found that the non-destructive method is more effective and doesn’t require weighing or drying and weighing the whole tree to estimate its biomass. Adhikari.M , 2015 added, though this method is efficient in terms of time and cost as compared to the full tree harvest method, it is still destructive to the tree i.e. it requires felling.
With the time and observed development in the used tools for the non-destructive method, as indicated by Soepadmo.E ,1993 had to climb the tree to measure the various parts in his study about estimated the carbon sinks in the rain forest, after that Montes.N, et al, 2000 developed a new method by taking two orthogonal-view photographs for each tree in samples then using the volume and the density of each component (trunks/branches, branchlets, leaves and, female cones), regression curves were established between densitometric parameters for trees (tree height crown projection area) and their estimated biomass by this computer method, the accuracy of the method hinges on the representative density, which is governed by the different pixels sampling for photographs, after few years Adhikari.M, 2005 verified whether Montes method to estimate single tree volume and biomass gives an accurate estimate of the tree volume and explore the potential of remote sensing techniques, combined with non-destructive tree volume and biomass assessment method (Montes method), he suggested an improvement to minimize the error associated with the

method by proposing a novel “model stem” method and validated the “model stem” method using a real tree example, the study concluded that the model stem method is more accurate and easy to adapt as compared to the Montes method for the volume assessment of individual trees due to its minimized the error that occurred due to branch tilting, by as much as 10 times as compared to the Montes method. Later in several studies, the biomass has been estimated by using the allometric equations which depend on measuring the parameters of a tree (diameter at breast height, the height of the tree, volume of the tree, and wood density) (Rodriyuez.A, 2017 , Bernasconi.L, et al, 2017).

Vashuam. K, 2018 commented a result that this method does not involve felling of tree species, it is not easy to validate the reliability of this method, therefore, it can also involve a lot of labor and time and climbing can be troublesome.

In this context Han.S and Park.B, 2020 have compared between the allometric equation and destructive measurement of naturally regenerated Understory in a Pinus rigida Plantation in South Korea. The plant component (i.e., foliage, branch, and stem) for understory trees with(DBH less than 10 cm) was compared. The estimated biomass using allometric equations for foliage, branch, and stem was lower than the values obtained using the destructive method by 64%, 41%, and 18%, respectively, consequently the authors worked on developing specific allometric equations for understory tree species and therefore suggests that more biomass allometric equations should be optimized for small-DBH trees to improve forest carbon stock estimation.

In simple terms Liang.S and Wang.J , 2020 have presented a clarify about the basic principle of the allometric equations is that in many organisms, the growth rate of one part of the organism is proportional to that of another. For example, the trunk diameter of a tree is highly correlated with trunk weight. If a range of tree sizes is measured, a regression equation can be derived for predicting tree weight. Since tree diameter is easy to measure but tree weight is much more difficult to determine, this gives a relatively easy way to estimate the standing biomass.

For this reason, FAO and the International Fund for Agricultural Development (IFAD) have set out to develop and test a methodological framework of procedures for measuring, monitoring and accounting for carbon stocks in biomass and in soil by Hernandez.R , et al, 2004, according to that Picard.N , et al , 2012 have developed a specific manual for building tree volume and biomass allometric equations, the form of a guide intended for all students, technicians or researchers working to assess forest resources such as volume, biomass ,and carbon stock, there methods described can apply to most forests and ecological areas, but the special emphasis has been placed on the tropical forest, more than the others, Mulat.A and Soromessa.T, 2017 one of the researchers who followed this guideline in their study to develop species-specific allometric equation non-destructively of the Millettia ferruginea in Tumata Chirecha KPA agroforestry Gedeo Zone_ Ethiopian, these allometric models significantly improved the capacity to accurately estimate biomass and consequent carbon stocks. Accordingly, it would create opportunities for sustainable management of agroforestry and to mitigate the climatic change in the study area.

Some publication tackled the field measurement method as the most accurate (Devi.L, Yadava.P, 2009), from the point of Vashum.K, 2012 it has some difficulties ,and technology is expected to provide a solution for these challenges by using remote sensing techniques.

According to NASA,2020 the term of remote sensing is defined as the acquisition of information from a distance, likewise USGS,2019 notified about it as the operation of detecting and monitoring the physical characteristics of an area by measuring it's reflected and emitted radiation at a distance, simply Al Ajmi.D, 2008 has reported that remote sensing techniques in daily life is closely much like in their principle of operation to Someone who viewing the screen computer monitor, with their three principal companied, the screen is a source of radiation it is starting to release light and passes over a distance while eyes as the sensor have to encountered and captured this light and finally send a signal to a processor (the brain) which records the data and interprets this into information, according to (NOAA,2020) experts reports the remote sensors are divide according to the source of energy, if it uses natural energy and reflected sunlight, it is known as passive sensors and it has a wide utilization, in contrast, active sensors which use internal stimuli like a laser. the literature has viewed several tools was employed for this technique such devices as cameras, lasers, radiofrequency receivers, radar systems, and others which can be implemented in a wide scope of application such as mapping and monitoring vegetation, due to their ability to record the physical properties of the environment and it has been recognized as a valuable tool for viewing, analyzing, characterizing, and making decisions about the environment (Shandilya.K, 2013).

In a few past years, several studies refuge to use remote sensing technique in agriculture researches due to the high result accuracy and the usability to assist in wide scope for various ecosystem, furthermore, in estimating AGB, Al-Hammadi .M and Glenn.E, 2007 use this technique in detecting date palm trees health and vegetation growth change on the eastern coast of the United Arab Emirates using SAVI (Soil Adjusted Vegetation Index), TM and ETM+ images from two dates, 1987 and 2000 were taken to enable the computation of the greenness anomalies combined with field measurements based on SAVI were analyzed, this remotely sensed data offered valuable information will help in managing and monitoring soil salinity conditions to achieve sustainability in productive of the date palm trees in study area, for the same purpose Allbed.A, et al, 2017 used multi-temporal Landsat data from different sensors to generate Normalized Difference Vegetation Index (NDVI) and Soil Salinity Index in Al Hassa Oasis in Saudi Arabia.

However, most related studies to evaluate the carbon forest storage and measuring biomass ,in general, want to use remote sensing data comparison with the data collected from the field (Li.Y,et al,2020 , Urbazaev.M, et al, 2018, Shashikant.V, etal, 2012, Menaca.J, 2017). Both Menaca.J et al ,2017 and Rodríguez.A, 2017 conducted a study to determine the performance efficiency of Terrestrial laser scanning (TLS) in estimating above ground biomass in the tropical forest for assessing AGB in Peru, Indonesia and Guyana, Menaca.J,2017 used a RIEGL VZ-400 measured 3D terrestrial laser scanner (RIEGL Laser Measurement Systems GmbH, Horn, Austria). This scanner is a discretized multiple-return LiDAR scanner the physical parameters were (DBH, tree height, the height of first branch ,and crown width) the DBH was measured with a forestry tape and tree height with a Nikon “Forestry, the quantitative structure models (QSM) was used for the largest tree per plot in three study sites and extracted point cloud and calculated its volume and converted to AGB using species-specific wood density, in addition to estimated AGB using pantropical and local allometric models furthermore a tree was harvested as a reference to take real measurements, the same procedures have been followed by Rodríguez.A, 2017 to test the most effective method for assessing the AGB of Mauritia flexuosa palms in a National Tourist Park, Peru, it is in the south of Iquitos city, Menaca.J,2017 notified that AGB estimates by the TLS-QSM method more accurate and less biased, comparison to destructive harvest measurements and the pantropical allometric models tested, while Rodríguez.A, 2017 observed a similarity between AGB estimates from allometric equations using stem height from field and TLS in both palm species with differences between 10 to 40 kg, they guessed the variances are mainly back to the difference in the measuring method either in fieldwork data or from point clouds, in general overall AGB from QSM is higher than AGB from allometric equations. Whereas both of them use the LiDAR remote sensing because of is designed to allow the signal to penetrate the canopy and this gave more accurate in the overcrowded forests, in another side TLS.M, et al, 2011 were previouslly used the terrestrial laser scanner (TLS) to estimate the AGB for pines *(Pinus sylvestrisL.)* and Norway spruces (Picea abies L.) individually in Finland, the study conducted to make investigations between measured field biomasses and terrestrial laser scanning (TLS) measurements based on tree crown and stem diameters, This indicates that there is an obvious development in TLS technique that has allowed for Menaca.J et al ,2017 and Rodríguez.A, 2017 to access fully assessing and draw forests, not just the stem and the crown, as in Holopainen.M, et al, 2011 study.

Tomppo.E, et al, 2002 developed a multisource method for estimating large area tree stem volume of growing stock and AGB of tree for woodland with the dominant tree species, in order of proportional representation, Scots pine *(Pinus sylvestris. L)*, Norway spruce *(Picea abies(L.) Karsten*) and birch *(Betula spp.)* which located in the northern part of Sweden. Six types of input data were collected for the analysis. Mainly combined Landsat-TM data and IRS-1C WiFS data, together with field data of National Forest Inventories (NFIs) were applied. The study concluded the possibility of applying this approach for biomass estimation at a continental level.

2.4 Measuring the Biomass in Desert Ecosystem

The majority of literature reviewed was conducted in humid semi-humid tropics, in counter to the arid and semi-arid region which found a little interest for application remote sensing technique there. Eisfelder.C,et al, 2011, Issa.S, et al, 2020 are one of the pioneers whom interest to study the desert ecosystem, both of them provided a serious work in reviewing multi different studies related to the utilization of remote sensing technique in estimation AGB and assessing carbon storage in arid and semi-arid zones. the articles which deal with using optical data, radar data, combined multi-sensor approaches and modeling approaches were presented by Eisfelder.C,et al, 2011, while Issa.S, et al, 2020 in wide scope made a comparison between the traditional methods ,and spatial technologies (i.e., remote sensing (RS) and Geographic Information Systems (GIS) for above ground biomass (AGB) estimation and carbon management, both of them discussed the challenge's which obstruct in using the remote sensing in this region and defined in low splattered vegetation which causes to high reflectance in soil background, signal-to-noise ratios, presence of biological soil crusts, high spatial heterogeneity from plot to regional scales, and irregular growing seasons due to unpredictable seasonal rainfall and frequent periods of drought, on the other hand, Eisfelder.C,et al, 2011 added the benefits of using RS technique through the possibility to monitor large areas and to capture the spatial variability of the land surface, in addition to the repeatability of data collection that offers the possibility for time-series analyses. Moreover, remote sensing has the capacity for systematic observations at different scales from global to local and the potential of using historical data.

to reduce the effect of soil background Svory.M, et al, 2002 conduct a study to modified the water-cloud model to estimate of areal aboveground biomass (AAB) of herbaceous vegetation in the semi-arid zone in Israel, based on previous studies five assumptions for the application of the water-cloud model to vegetation canopies were specified, one of this assumptions were applied with the consideration of habitat conditions and vegetation cover state, the results show that the modified model estimations are in agreement with actuated measurements from the semiarid zone of central Israel.

This may imply that the water-cloud model could be implemented in areas of sparse herbaceous canopies using ERS-2 SAR data when combined with additional information about vegetation cover, for the same purpose Wang.G et, 2018 conduct another study to improve the performance of AGB estimating models based on Modified Vegetation Indexes (MVI) _ which widely used to estimate AGB at a regional scale_ by minimizing the influence of the soil background for a typical semi-arid grassland in Inner Mongolia, northern China , the methodology depended on both field sampling and remote sensing from MOD09A1 (TERRA satellite) to acquire the data. The study concluded that is for estimation the AGB in grassland the performance of MVI-AGB models is better than that of VI-AGB models and can help predict the ecosystem response under climate change.

In another study Xing.W et al , 2103 use of microwave remote sensing for estimating vegetation biomass is limited in arid grassland regions located in the Qinghai Province, China. While the study of Eisfelder.C, et al, 2016 differ from the previous in inclusion shrubs under the frame of work for developing a suitable approach biomass estimation in Kazakhstan, based Net Primary Productivity (NPP) data, which was covered at the years 2003–2011 for input data related to climate and phonological, the modified approach based on the internal relation for plant’s absolute growth rate which is NPP description it, between the amount of plant biomass and its relative growth rate (RGR) the last was used to derive the plant’s standing biomass from NPP. in addition to the field measurement to achieve more validation , Study recommended to do more experimental studies with plants typical to reduce the error as a result to the difference between the field data estimates and NPP-based above-ground grass biomass estimate, likewise chen.W, et al, 2018 paid much attention to estimating AGB for shrubs in China Mongolia Region, the study depended on statically method to analyze the remote sensing data as image from Landsat Thematic Mapper (TM) and data from field measurement for building the linear models correlation with Ratio Vegetation Index (RVI) .

In particular (Reinermann.S, et al, 2020) strived to offer an article included a full list of reviewed research articles related to using remote sensing technique for estimation AGB in pasture and grassland. Unfortunately, there is an obvious gap towards the assessment of AGB for trees in this ecosystem. On this side, the majority of studies conducted in this region was a target to developing a specific approach to estimate the biomass for tree woody species (Navar.j, et al, 2019, Koala.J, et al, 2017 and Tamene.L, et al, 2016) in this context, Issa.S, et al, 2018 observed there is not any of developed modeling could use to fit one of the most important fruit crops (Phoenix dactylifera, date palm) in the arid regions, that motivated them to put much effort to develop a specific allometric biomass estimation equation for date palm, furthermore, Issa.S, et al, 2019 are considered to be the pioneers in using remote sensing and Geographic Information Systems (GIS) for mapping vegetation for accurate measuring of date palm biomass in Abu Dhabi, for this, Six Landsat-8 OLI scenes covering Abu Dhabi emirate were pre-processed, pan-sharpened, and combined to build a single large mosaic, then, a thematic map of date palm (DP) plantations was built by distinguishing between DP and non-DP classes. the authors also provided equations, furthermore Issa.S, et al, 2018 observed there is not any developed modeling that could use to fit one of the most important fruit crops (Phoenix dactylifera, date palm) in the arid regions, which motivated them to put much effort to develop a specific Allometric biomass estimation equation for date palm.

They also provided the equations which can use for assessing the AGB and CS in mature date palm tree farms on wide area, the study recommended to use more detailed satellite imagery for delineating young date palms was a little harder to achieve requiring director do it manually, for such statues a specific equations have been developed to estimate AGB for each date palm age classes by Issa.S, et al, 2018 in UAE, both of the destructive method and remote sensing approach were applied in two detached phases, for developing a new specialized mathematical equation eight varieties were chosen in three age classes (Class 1, covering plantations with age < 5years; class 2, with age between 5 and 10 years; and class3, covering matured forests exceeding 10 years age), five-date palm trees were uprooted for each age class for uprooted and were partitioned into three parts: crown, trunk and roots , for building up specific biomass allometric equations the structural parameters were measured before uprooted to be used later in the multi-regression analysis. as for the variables which were measured various previous studies were pointed it () which including (Number of palm fronds, Palm height, Palm trunk height, Crown depth, a difference between total and trunk (Δ height), crown diameter (CD), Crown area (CA) was calculated using sphere equation (CA= π $CD^2/4$) and the DBH in cm by measuring the circumferences of the trunk at 1.3 m height and dividing by π. For the small palms where there is no trunk developed yet, the diameters were measured at the base of the palm, after that many RS variables were tested for their ability to predict biomass of Date Palm by using Landsat 8 bands and vegetation indices (VI's) the study recommended for use the equations which developed for estimation the AGB and assessing the carbon storage, additionally this is the only study that discusses species (Phoenix dactylifera, date palm) while Rodríguez.A, 2017 developed model to estimate AGB for two species of palms, Mauritia flexuosa and Mauritiella armata in the Peruvian Amazon. likewise Sunaryathy.P, et al, 2015 developed an equation for oil palm trees based on age classes, whereas both study of Khalid.H, et al, 1993 and Migolet.P, 2020 were limited to estimating the biomass of mature oil palm trees.
As for the Palestinian region, the majority of the study is concerned with the feasibility study for estimated the sustainability of the Date palm sector (Hanieh.A ,2020), in addition to analyzing the general pattern for farmers in Jericho (socio-economic)by Abu-reda,L , 2008, in another hand Abugesh.A, 2018 discuss the determinants of expanding palm tree cultivation in terms of land and water resources in the Jericho region, but this studies or others didn't look for the environmental side or assessing the quantitative growth of Date Palm tree in the region, hence our study focused on developing an environmental tool of date palm growth measurement in this arid area and it is similar with Issa.S, et al, 2018 study in the goal but our methodology limit with field measurement contrariwise, Issa.S who integrated satellite imagery with the destructive method for establishing a new equation related to Date Palm species, furthermore our study takes in consideration the effect of the age in AGB accumulation.

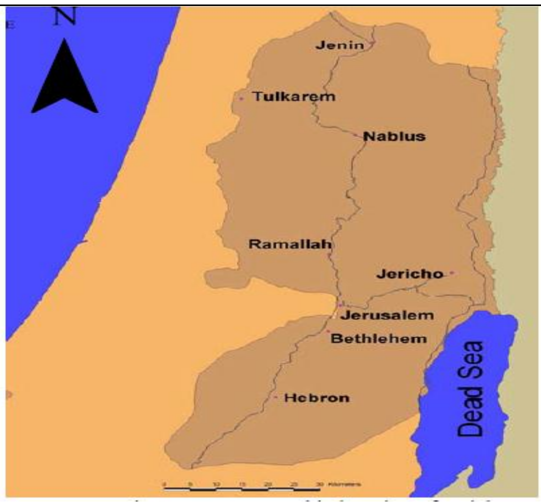
Chapter. 3

Methodology

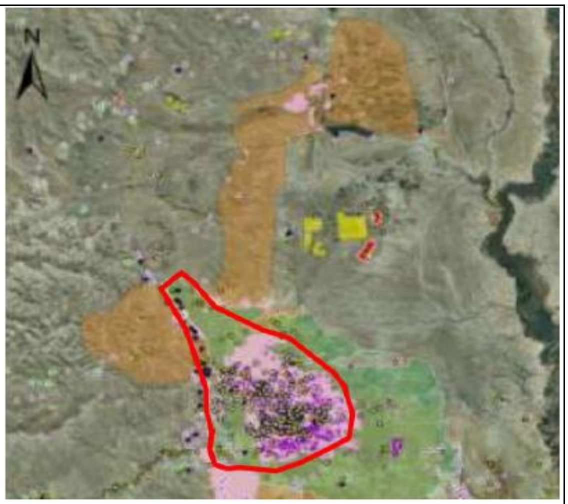
This chapter deal with the method of research procedures in terms of the description of the study methodology, the study sample ,and the method of plant structure measurement, through this chapter, we will present the procedures that have been followed in accordance with the scientific origins of scientific research to reach the final results ,and achieve the general aim of this study, in addition, to include the study area, study variables and statistical treatment.

3.1 Study site

The study site of field is located in Jericho Governorate which lies 250 meters below sea level at coordinate 31 º 52 N ” 35 º 26 E’ (Barkai _et., 2008), about 5Km to the northern of Dead Sea, (Fig 3.1). According to the Köppen climate Jericho has a hot desert climate, the analysis results of bioclimate data indicated for (Ighbareyeh, 2019) study that the mean monthly temperature was 22.4 0C, mean monthly minimum temperature was 15.3 0C, mean maximum temperature was 34.8 0C, annual rainfall is between 145-205 mm, most of which is concentrated in the winter season until early spring, It is thus one of the semi-arid regions of the Mediterranean basin.



Geographic location of Jericho



Location of the study area at Jericho

Figure 3.1 : Location of the study area (Rjoob.A, 2011)

The Jericho Station for Agricultural Research (JSAR) has been selected purposively as a case study, it has a wide range of common cultivars traded among farmers, the plantation did under controlled conditions and well-defined strategy. The records of farm operations can easily be accessed, this allows us to generalize the results and the possibility of applying them to other farms.

The station was established in an area of about 80 dunum. JSAR station interested in many research fields in addition to the Date Palm trees, there are many experiments in the protected cultivation of municipal varieties of vegetables, fresh water has been used for irrigation field of Date Palm tree and the salinity of soil is about 1 ds.

3.2 Methodology

3.2.1 Study tool

Field measurements were taken manually using a measuring tape (1 mm precision). For processing and analysis data, excel package and Spss Software were used. It has been a focus on three common varieties in JSAR (Medjool, Berhi, Degla-Nour).

3.2.2 Methods

The methodology can be divided in to two main stages: estimating above ground biomass (AGB) for three date palm cultivars and developing the correlation between Date Palm biomass and their structure parameters of tree, as shown in (Fig 3.2)

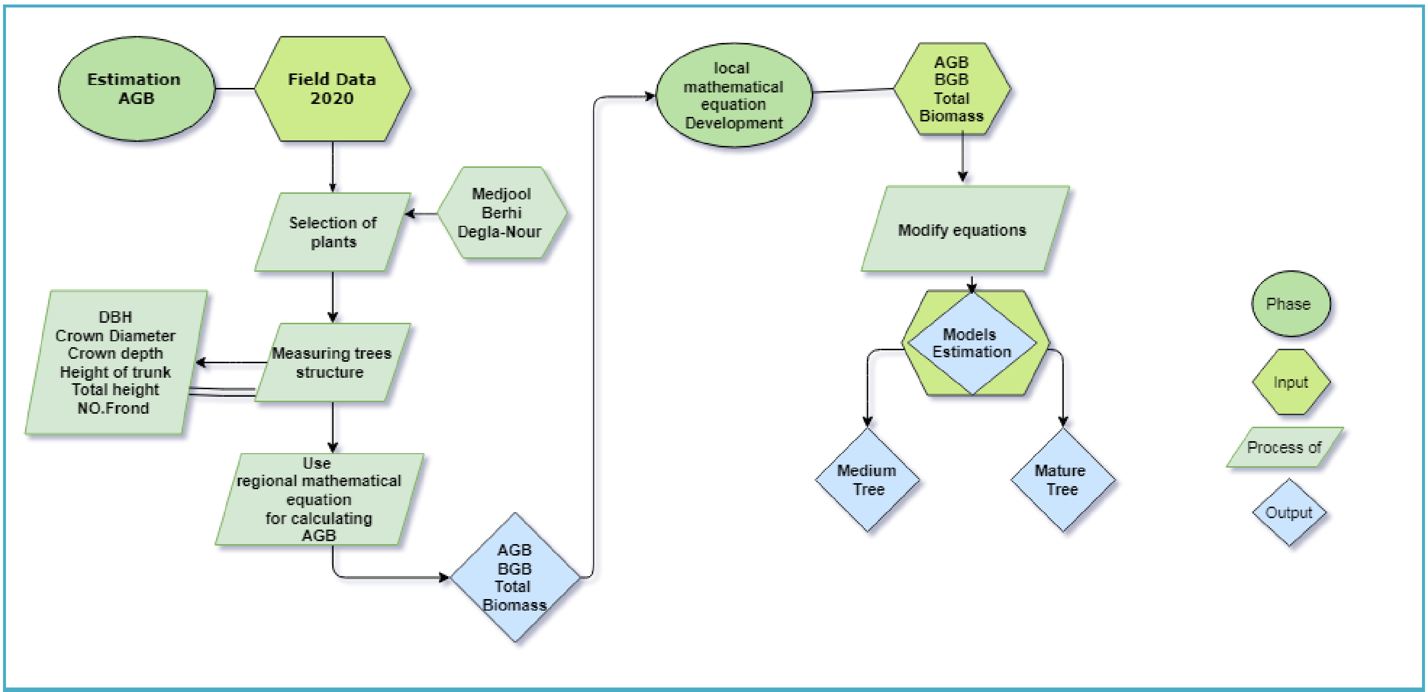


Fig3.2: This figure in detail shows the procedures dealt with in the methodology of the study, begin with estimating the AGB of Date Palm trees by adopting field measurements then developing a specific equation for assessing AGB

3.2.2.1 Estimating AGB

To evaluate AGB a non- destructive method was adopted which depends on field measurement for structural parameters of Dates Palm trees at the year 2020, furthermore from available data sources and reviewing the previous literature a regional model of the mathematical equation was adopted for estimation AGB.

3.2.2.1.1 Sample selection and data collection

- Sampling of plants

The sampling method depends on the aim of the study. Therefore a survey sample consisting of one hundred thirty-four Dates Palm trees were chosen at the age ranges between (5 - 12) years, based on the data provided by the JSAR station records for three cultivars Medjool, Berhi ,and Degla- Nour (thirty trees for each cultivar), all of the trees are under the same ecosystem (soil characters, irrigations water) and the same agriculture practices, field scheme (appendix 3. 1)

- Data collection (Field measurements)

Generally, a Date Palm tree consists of different parts, our study focuses on the structural parameters of the Date Palm tree as shown in (Fig 3.2).

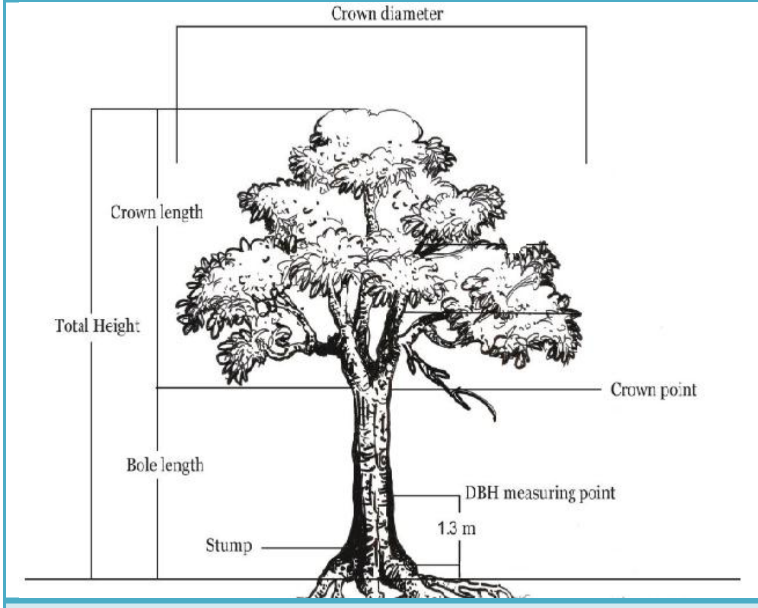


Fig 3. 3: Illustration of different parts or components of a tree, which constructed the tree structure that be measured, FAO,2016

The field measurements of crown and trunk were conducted during September 2020 before harvest season, (Issa.S, et al, 2018 & Hossain.M, 2016) recommend that the time of measurement must to be considered in the period in which most of the plant species flush new leaves, flowers and fruits during the spring or before harvest, to get maximum biomass despite the study of Issa.S, et al, 2018 recommended to select (CA and Ht) for measuring the AGB but what must be taken into consideration is the difference in environmental condition as soil characters, agriculture practice, and climate which may effect on vegetation growth for the tree, therefore we measure all structure parameters of the tree due it a first time for building a local equation, and the measurements as following, and the measurements as following.

DBH is the most common method of measuring tree dimension, refers to the diameter of a tree trunk measured at breast level, it measured at 1.3 m from the ground level. When taking a measurement with a tape we have to ensure the tape lies flat and is not obstructed by any swollen parts of the trunk by moving it around the trunk and re-tighten it accurately as shown in (Fig 3.4)

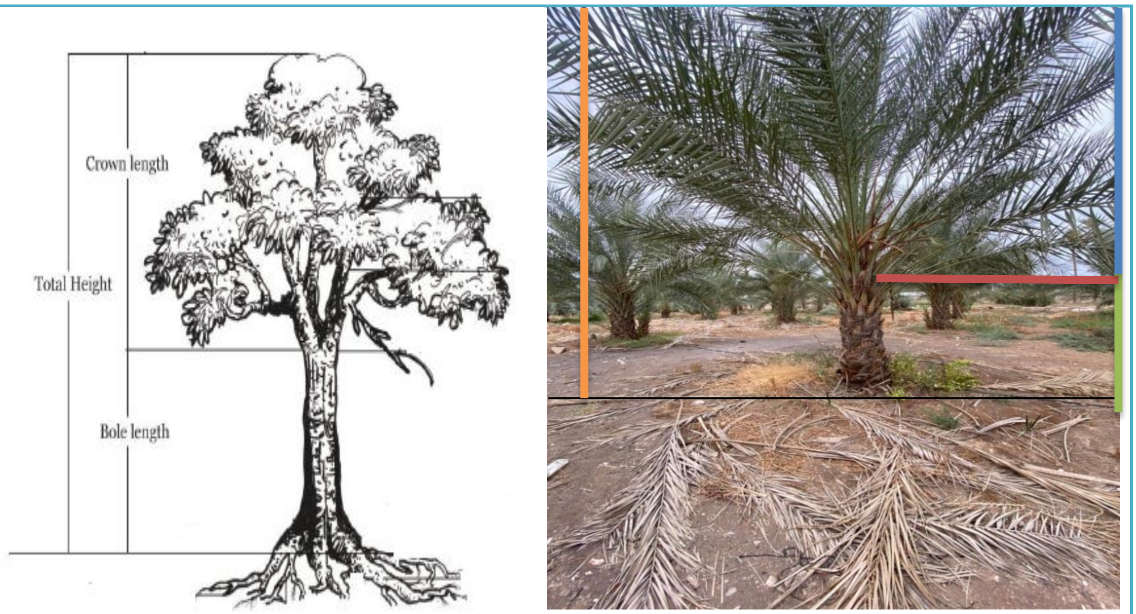
Fig 3.4: The mechanism of measuring DBH manually

Trunk Height : This measurement needs to be taken from the height from cutting end of stump to crown point as (Fig 3.5)

Fig 3. 5: The mechanism of measuring height of trunk manually

Total Height measures the height from cutting end of stump to pot green point of the tree. Or calculate it mathematically as (fig 3.5) through equation 1 .

Total Height = trunk length + Crown Depth ………. .equation 1



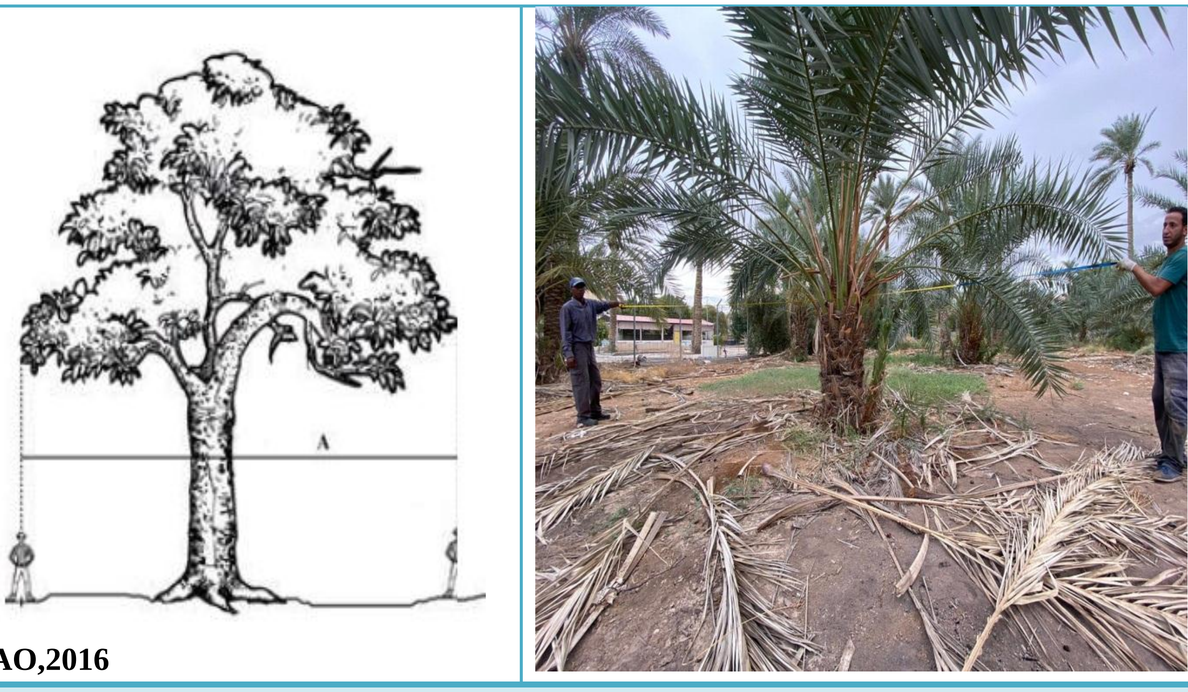
FAO,2016

Total Height **Crown Depth**
Trunk length

Fig 3.6 : The figure present the tree structure that equation depends on

Crown diameter

By chosen the widest side of the crown we measure the diameter of the crown projection from one side to another, and it is important to be considered correct the slope frond distance to horizontal distance.



FAO,2016

Fig 3.7 : Measurement Date Palm crown diameter

Crown Depth

The vertical distance from crown forming point to the top of the tree green growth it's a Crown Depth, measuring by using tab 5m.

Fig 3.8 : Measurement Crown Depth of Date Palm tree by FAO, 2016

Fig 3.9 :The figure show how we can measure crown depth for Date Palm tree

Number of frond : The fronds was counted before harvesting season as shown in fig 3.10.

Fig 3.10: Counted the Dates Palm frond

3.2.2.1.2 Date Palm Biomass Calculation

Mathematical equations were adopted in calculating tree biomass based on (Issa.S, et al, 2018) study, which recommended a different mathematical equation for each age stage (young and medium). In this study we will use the equation related to both stage.

For young tree the equation of AGB estimation limited on crown biomass measurement as

$$\textbf{AGB} = \textbf{Crown Biomass} \qquad \textbf{(1)}$$

As medium and mature tree the equation is

$$\textbf{AGB} = \textbf{Crown Biomass} + \textbf{Trunk Biomass} \qquad (2)$$

Where

$$\textbf{Crown Biomass} = 14.034 * 1.057 \wedge CA \qquad (3)$$

And

$$\textbf{Trunk Biomass} = -3.956 * (Ht)^2 + 55.247 * (Ht) - 2.0342 \qquad (4)$$

CA: Crown Area (CA = $\pi\ CD^2/4$)
Ht : Trunk Height

While

$$\textbf{Total Biomass = AGB + BGB} \quad (5)$$

AGB : Above Ground Biomass
BGB : Below Ground Biomass

The BGB ratio calculations were developed by the researcher tacking in considerations Issa.S, et al, 2018 mathematical calculations as the following

And

BGB for young tree **= 0.816 * AGB** (6)

BGB for medium tree = **0.496 * AGB** (7)

BGB for mature tree = **0.248 *AGB** (8)

3.2.2.2 Correlation between AGB of and field variables.

Excel package was used for calculating the component of Date Palm biomass (AGB, BGB, total), then found the correlation between field variables (tree structure parameters) and measured variables by Spss Software, in addition, to studying the variance in variables using (ANOVA test and T-test) and the optimal model between relationships for estimation AGB is found by standard regression test.

Chapter . 4

Result and Discussion

4. Result and Discussion

This chapter deals with collected data which organized and analyzed using software (SPSS, version.23), whereas the statistical tests have been carefully chosen to obtain accurate results commensurate with the importance of the study, as well as presenting the research results in order to be used by decision-makers in future expansion and investment plans, in addition, to be available for involved people.

4.1 Descriptive statistics of - the collected data

According to the preliminary results, all of the field parameters of the study (DBH, H, Ht, CA , CD,Cd, #No. Fronds) have a normal distribution (appendix 4.1), which authorized us to use parametric tests. It is found that the AGB was significantly related to Date Palm component parameters (Crown , Trunk) for all samples which measured, whether for trees in the same age classes within different varieties group, or which measured for three different age classes for one Date Palm variety, (appendix 4.2).

4.1.1 Descriptive statistics of field parameters

The descriptive statistics of field parameters which use for calculation the AGB for each different varieties and the age classes have been summarized in (Table4 .1, Table 4.2) respectively.

Generally, there are differences appear in (table 4.1) between the mean of the measured field parameters for the three varieties for example the DBH has a similarity in a mean of Berhi and Degla Nour while Berhi has a maximum value reached 79.61 whereas the maximum value of Degla Nour is 65.28 , in the other hand both of Medjool and Berhi have a similar value of mean except Degla Nour has a higher rate in trunk growth.

Table 4.1 . Descriptive statistics for the field parameters of Date Palm varieties

Variety	Age Year	N	Components (Unite)	Mean	SD	Minimum	Maximum
Medjool	5 ≤ Years ≤ 10	30	DBH* (cm)	50.46	8.22	35.03	65.28
			H (m)	5.04	0.68	3.78	6.60
			Ht (m)	1.94	0.45	1	2.7
			CA**(m2)	25.33	6.25	7.54	35.24
			CD (m)	5.6	0.77	3.1	6.70
			Cd (m)	3.02	0.35	2.25	3.6
			No. Fronds	32	4.93	25	45
Berhi	5 ≤ Years ≤ 10	36	DBH* (cm)	54.90	18.56	28.66	79.61
			H (m)	5.17	0.65	2.90	6.3
			Ht (m)	2	0.34	0.8	2.80
			CA**(m2)	37.52	6.97	12.74	50.24
			CD (m)	6.8	0.70	4.03	8
			Cd (m)	3.17	0.36	2.10	3.95
			No. Fronds	30	5	14	43
Degla-Nour	5 ≤ Years ≤ 10	26	DBH* (cm)	55.28	12	46.17	65.28
			H (m)	5.59	0.57	4.25	6.40
			Ht (m)	2.38	0.37	1.75	2.90
			CA**(m2)	41.39	4.42	30.18	46.91
			CD (m)	7.25	0.4	6.20	7.73
			Cd (m)	3.21	0.30	2.50	3.80
			No. Fronds	37	6	25	50
DBH*	Calculated from the equation of circumference of a circle, $DBH = C/\pi$						
CA**	Calculated from the equation of surface area of sphere, $CA = \pi * CD^2/4$						

As for the group samples within different age class of Medjool, the result of descriptive statistics (table 4.2) shows a high correlation between parameters, furthermore, there is an increase observed in growth for variables (H, Ht,) at the mature phase with percentage (%97.42, %253.6) respectively than the medium phase which percentage increase about (%64.71, %138) respectively, on the contrary (CA, DBH) variables have a higher percentage in age class two than the class three with a growth percentage (%95.15, %50.4),(80.65, 7.09) respectively. The result is related to

#NO. Fronds have an increase in percentage (%50) in class three (mature tree) than previous age class (medium tree).

Table4. 2: Descriptive statistics for the field parameters within the same variety while different age classes

Variety	Age	N	Components (Unite)	Mean	SD	Maximum	Minimum
Medjool	Year < 5	6	DBH* (cm)	33.55	11.87	54.14	19.75
			H (m)	3.06	0.391	3.63	2.80
			Ht (m)	0.815	0.233	1.17	0.57
			CA**(m2)	12.98	5.52	19.39	4.71
			CD (m)	3.98	0.937	4.97	2.45
			Cd (m)	2.44	0.283	2.78	2.15
			No. Clusters	-	-	-	-
			No. Fronds				
Medjool	5 ≤ Years ≤ 10	30	DBH* (cm)	50.46	8.22	65.28	35.03
			H (m)	5.04	0.68	6.60	3.78
			Ht (m)	1.94	0.45	2.7	1
			CA**(m2)	25.33	6.25	35.24	7.54
			CD (m)	5.6	0.77	6.70	3.1
			Cd (m)	3.02	0.35	3.6	2.25
			No. Clusters	8	3.65	14	0
			No. Fronds	32	4.93	45	25
Medjool	Year < 10	36	DBH* (cm)	54.02	3.89	65.92	47.45
			H (m)	9.95	0.929	11.50	8.20
			Ht (m)	6.86	0.951	8.20	5.08
			CA**(m2)	45.76	1.47	48.37	43.22
			CD (m)	7.63	0.121	7.85	7.42
			Cd (m)	3.09	0.115	3.35	2.90
			No. Clusters	12	3.5	5	20
			No. Fronds	58	9.57	35	75
DBH*	Calculated from the equation of circumference of a circle, $DBH = C/\pi$						
CA**	Calculated from the equation of circumference of a circle, $CA = \pi * CD^2/4$						

4.1.2 Descriptive statistics of biomass measured

Based on the previous field parameters in (table 4.1, table 4.2), biomass has been calculated and the result of descriptive statistics are present in (table 4.3) for the set of varieties within the same age class and Medjool with different age class in (table 4.4), we can observe from (table 4.3) that the varieties have a variance in the mean of biomass components, but we can't be certain if it is statically significant, whereas Berhi has the heights most maximum value in total biomass but Degla Nour has the highest value in the mean of the total biomass.

Table 4.3 : Descriptive statistics of AGB components for Date Palm varieties within the same age group

Variety	Age Year	N	Components (Kg)	Mean	SD	Minimum	Maximum
Medjool	5 ≤ Years ≤ 10	30	Crown Biomass*	67.29	19.01	21.32	98.98
			Trunk Biomass*	89.64	21.4	45.30	125.77
			AGB**	149.93	37.12	80.95	211.64
			BGB***	74.36	18	40.15	104.97
			Total Biomass**	224.23	55.52	121.11	316.62
Berhi	5 ≤ Years ≤ 10	36	Crown Biomass*	119.69	40.33	28.44	227.36
			Trunk Biomass*	92.95	16.4	35.8	130.5
			AGB**	212.64	50.56	64.27	322.83
			BGB***	105.47	25.08	31.88	96.15
			Total Biomass**	318.11	75.71	31.88	482.96
Degla-Nour	5 ≤ Years ≤ 10	26	Crown Biomass*	142.87	29.84	74.76	188.99
			Trunk Biomass*	109.3	17.1	135.24	80.80
			AGB**	252.21	43.93		155.65
			BGB***	125.09	21.79	77.16	156.60
			Total Biomass**	377.31	65.72	232.72	472.33
			(*) : Measured and calculated according to equation of (Isaa.S, et al, 2018)				
			(**) : Calculated mathematically				
			(***)The ratio calculations were developed by the researcher tacking in considerations Issa.S, et al, 2018 mathematical calculations				

The following results in (table 4.4) presented the vegetation development of Medjool between the age range 5 -12 years, it's clear that trees at the mature phase have stable growth was a minor variance between the maximum and the mean value for measured variables.

Table 4.4 : Descriptive statistics of AGB components for Medjool within different age classes

Variety	Age Year	N	Components (Kg)	Mean	SD	Minimum	Maximum
Medjool	Year < 5	6	Crown Biomass*	29.92	8.71	18.22	41.12
			Trunk Biomass*	_	_	_	_
			AGB**	29.92	8.72	18.22	41.12
			BGB***	6	1.22	4.32	7.66
			Total Biomass**	35.93	9.66	24.25	48.76
Medjool	5 ≤ Years ≤ 10	30	Crown Biomass*	67.45	24.31	28.55	147.35
			Trunk Biomass*	89.64	21.4	45.3	125.7
			AGB**	149.904	37.11	80.95	211.64
			BGB***	74.36	18.40	40.15	104.97
			Total Biomass**	224.28	55.51	121.11	316.62
Medjool	Year > 10	36	Crown Biomass*	177.95	14.51	154.06	205.01
			Trunk Biomass*	322.57	45.02	238.43	386.11
			AGB**	500.53	46.168	392.49	578.97
			BGB***	124.13	11.45	97.34	143.58
			Total Biomass**	624.66	57.62	489.83	722.55
			(*) : Measured and calculated according to equation of (Isaa.S, et al, 2018)				
			(**) : Calculated mathematically				
			(***)The ratio calculations were developed by the researcher tacking in considerations Issa.S, et al, 2018 mathematical calculations				

Furthermore based on those result (table 4.4) we can develop a ratio of biomass for each age class as the following section.

4.2 Biomass Ratio

The following (table4.5) present the development of the biomass components parts of date palm trees in the age groups (young, medium, mature), the results of the young tree group show an observed increase in the contribution of crown biomass which was 83% of total biomass, where 17% for BGB. As for the medium phase, it can be described as the balance stage in the Date Palm life cycle, because of the convergence in the percentage of the contribution of the three components of total Date Palm biomass, In contrast to the young palm, the above-ground biomass in a mature tree has the highest contribution from trunk biomass which reach 64% to AGB, while crown biomass and below-ground biomass decrease to 36%, 25%, respectively from AGB.

Table 4.5 : Biomass Ratio For Date Palm Tree

		Young (Years < 5)	Med (5 ≤ Years ≤ 10)	Mature (Years < 10)
Total Biomass	% Crown Biomass	83	34	29
	% Trunk Biomass	_	33	51
	% Below Biomass	17	33	20
	% AGB	83	67	80
AGB	% Crown Biomass	100	50	36
	% Trunk Biomass	_	50	64
	% Below Biomass	5	50	25

4.3 The Analysis Of Variance

4.3.1 The variance of varieties in AGB component

The normal distribution of the study variables authorized us to make One-way analysis of variance test for biomass components measurement which statistically significant if it refers to varieties, as following.

Table 4.6: Result of ANOVA Test of crown biomass

Crown biomass for Date Palm tree depending to varieties	Mean	SD	F	Sig. Value	Significant
Medjool	67.29	19.01	39.605	0.000	Significant
Berhi	119.69	40.33			
Degla-Nour	142.87	29.84			

From the previous table, it is clear that there are statistically significant differences at the level of significance (α<0.05) in the weights of crown biomass of the date palm trees due to the variant of the variety.

To find the source of variation within groups, Tukey test was performed (appendix 4.3), and the result present that the variance in weight of crown biomass for Date Palm tree depending on variety refers to Degla-Nour within three groups which have a higher mean for crown biomass weight with value = 142.87 Kg/Palm in(table 4.6).

Table 4.7: Multiple Comparisons (Tukey) Test

Variable	Comparisons	Medjool	Berhi	Sig	Degla-Nour	Sig
Crown Biomass	Medjool		-52.24119*	0.000	-75.42874*	0.000
	Berhi	52.24119*		0.000	-23.18755*	0.020
	Degla-Nour	-75.42874*	23.18755*	0.020		

The result present that the variance in weight of crown biomass for Date Palm tree depending on variety was significant between Medjool and Berhi groups benefit of Berhi group due to it has a higher mean than as shown in (table4.7), while the benefit to Degla-Nour when comparisons within Berhi and Degla-Nour group.

AS for the component of trunk biomass, the result shows that there are statistically significant differences at the level of significance (α<0.05) in the weights of trunk biomass of the Date Palm trees due to the variant of the variety. Tukey test was performed to find the source of variation within groups (appendix 4.3) and it's presented that the variance in weight of trunk biomass for Date Palm tree depending on variety refer to Degla-Nour within three groups which have a higher mean for trunk biomass weight with value = 109.21 Kg/Palm as shown in (table 4.8)

Table 4.8: Result of ANOVA Test for trunk biomass

Trunk biomass for Date Palm tree related to varieties	Mean	SD	F	Sig. Value	Significant
Medjool	89.64	21.44	9.119	0.000	Significant
Berhi	92.95	16.34			
Degla-Nour	109.21	17.05			

In connection with AGB the result shows that there are statistically significant differences at the level of significance (α<0.05) in the weights of AGB of the Date Palm trees due to the variant of the variety. Tukey test was performed to find the source of variation within groups and it's presented that the variance in weight of Above Ground Biomass for Date Palm tree depending to variety refer to Degla-Nour within three groups which has a higher mean for trunk biomass weight with value = 252.21 Kg / Palm as present in (table 4.9)

Table 4.9 : Result of ANOVA Test for AGB					
Above Ground Biomass for Date Palm tree depending to varieties	Mean	SD	F	Sig. Value	Significant
Medjool	149.90	37.12	37.791	0.000	
Berhi	212.64	50.55			
Degla-Nour	252.21	43.93			

As for BGB, the result shows that there are statistically significant differences at the level of significance (α<0.05) in the weights of AGB of the date palm trees due to the variant of the variety. Tukey test was performed to find the source of variation within groups and it's presented that the variance in weight of AGB for Date Palm tree depending to variety refer to Degla-Nour within three groups which has a higher mean for BGB weight with value = 125.1 Kg / Palm as shown in (table 4.10).

Table 4.10 : Result of ANOVA Test for BGB					
Below Ground Biomass for Date Palm tree depending to varieties	Mean	SD	F	Sig. Value	Significant
Medjool	74.36	18.41	37.774	0.000	
Berhi	105.47	25.08			
Degla-Nour	125.10	21.79			

In connection with total biomass, it is clear to us that there are statistically significant differences at the level of significance (α<0.05) in the weights of the total biomass of the date palm trees due to the variant of the variety. To find the source of variation within groups, Tukey test was performed, and the result present that the variance in weight of total biomass for Date Palm tree depending to variety refer to Degla-Nour within three groups which have a higher mean for crown biomass weight with value = 377.31 Kg/Palm as shown in (table 4.10).

4.3.2 The variance of varieties in field structural parameters

The result relater to one-way analysis of variance for field parameters shows that there are statistically significant differences at the level of significance (α<0.05) in the (DBH, H, Ht, CA, CD, #No. Clusters, NO. Fronds) parameters of the date palm trees due to the variant of the variety. Tukey test was performed to find the source of variation within groups and it's presented that the variance in DBH for Date Palm tree depending to variety refer to Berhi group which has a higher mean with value = 58.36 cm then Degla-Nour is followed with mean = 57.68. As for other parameters (H, Ht, CA, CD, NO. Clusters, NO. Fronds) the Degla-Nour excels within groups in its means with value (5.57, 2.38, 41.39, 7.25, 11, 37) respectively as shown in (table 4.11).

Table 4.11: Result Of ANOVA Test For Field Parameters

Parameter	N	Variety	Mean	SD	F	Sig. Value
DBH	30	Medjool	50.46	8.22	6.273	0.003
	36	Berhi	58.36	12.95		
	26	Degla-Nour	57.68	4.59		
H	30	Medjool	5.04	0.68	5.608	0.005
	36	Berhi	5.17	0.66		
	26	Degla-Nour	5.59	0.57		
Ht	30	Medjool	1.94	0.45	10.949	0.000
	36	Berhi	2.01	0.34		
	26	Degla-Nour	2.38	0.37		
CA	30	Medjool	25.33	6.25	54.702	0.000
	36	Berhi	37.52	6.69		
	26	Degla-Nour	41.39	4.42		
CD	30	Medjool	5.59	0.77	49.857	0.000
	36	Berhi	6.88	0.71		
	26	Degla-Nour	7.25	0.41		
Cd	30	Medjool	3.02	0.35	2.555	0.083
	36	Berhi	3.16	0.36		
	26	Degla-Nour	3.21	0.30		
#No. Fronds	30	Medjool	32	4.93	13.624	0.000
	36	Berhi	30	5.29		
	26	Degla-Nour	37	6.23		

4.3.3 The variance of AGB component depending on age

to analyze the variance in AGB component through consideration of age, T-test was performed and the result confirms that there are statistically significant differences at the level of significance ($\alpha<0.01$) in the weights of Date Palm trees biomass due to the variant of the age as presents in fig (4.12).

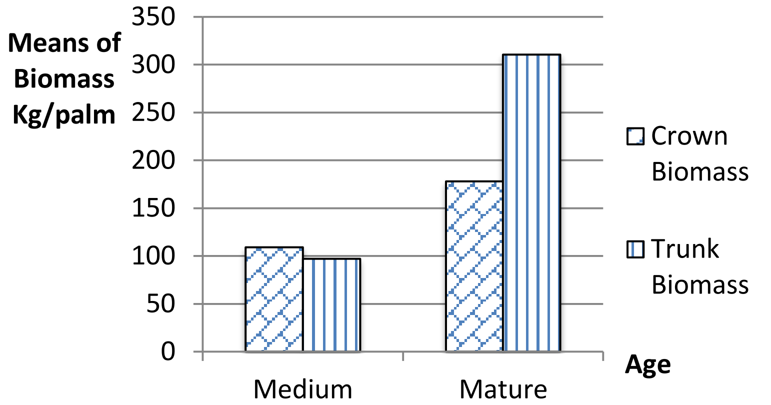


Fig 4.1: Result of T-test for variance in AGB component related to age

4. 4 Allometric Equation

In this section, we aim to study the relationship between each of AGB component with structural parameters of Date Palm tree.

4.4.1 Crown Biomass : In general all field parameters presented a positives significant correlation with crown biomass (Fig 4.2)

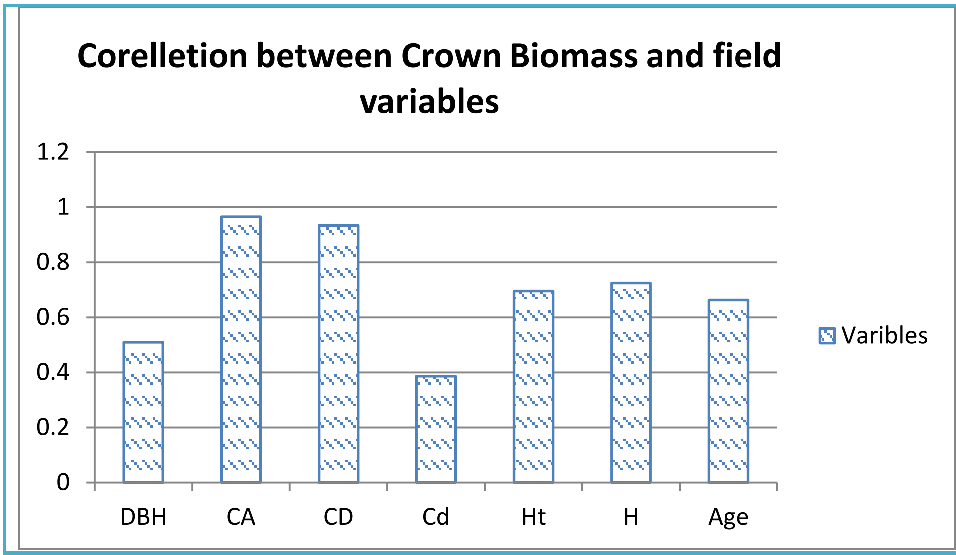


Figure 4.2 : Correlation relationship between field parameters and crown biomass

Both of (CA, CD) parameters have a high correlation with value (0.964, 0.933) respectively, while (H, Ht, age, DBH) have an intermediate correlation with crown biomass (0.724,0.695, 0.662, 0.509) respectively, and (Cd) has a weaker correlation with crown biomass. The correlation relationship between the field variables and the crown biomass does not completely reflect whether these variables have a real effect on the actual value of crown biomass and what is and what is influence extent, therefore standardized regression have been used to predict the value of the impact that the set of field variables have on the crown biomass, in addition, to find the fit regression equation between variables as follows.

Table 4.12: Regression relationship between crown biomass and field variables

Depends	Predictors Variable(X)	Beta	Sig	R^2	Optimal Regression Equation
Crown Biomass	DBH	-0.25	0.217	0.964	Y=17.895*(1.020 ^ X)
	Cd	0.063	0.184		Y=e ^ (6.440 + (2.506/X)
	CD	-1.597	0.000		Y= 1.949*(1.805^X)
	CA	2.398	0.000		Y=14.034*(1.057^X)
	Ht	0.128	0.600		$Y=-58.75+(111.41*X)+(-16.466*X^2)+(0.77*X^3)$
	H	- 0.061	0.815		$Y=-152.857++(68.132*X)+(-3.478*X^2)$
	Fronds	- 0.074	0.200		$Y=29.120+(-3.45*X)+(0.129*X^2)+(-0.001*X^3)$

It is evident from the previous table that there is a statistically significant relationship (effect) at the level of significance ($\alpha<0.05$) between the (CA, CD) and crown biomass and this compatible with Korom.A, et al, 2016 study which evaluation the AGB of oil palm tree , for a crown area the positive relationship effect was valued (Beta= 2.398), on the contrary, crown diameter, have a negative effect with (Beta = -1.597), whereas the following (figure 4.3) view the curve of regression relation between crown area and crown diameter with crown biomass, and it's clear that the representative points of the crown area are close more than those representative crown diameters from crown biomass, hence the result confirm that the CA is the best factor for estimation crown biomass with compound regression model and this model is similar with Issa.S, et al, 2018 equation .

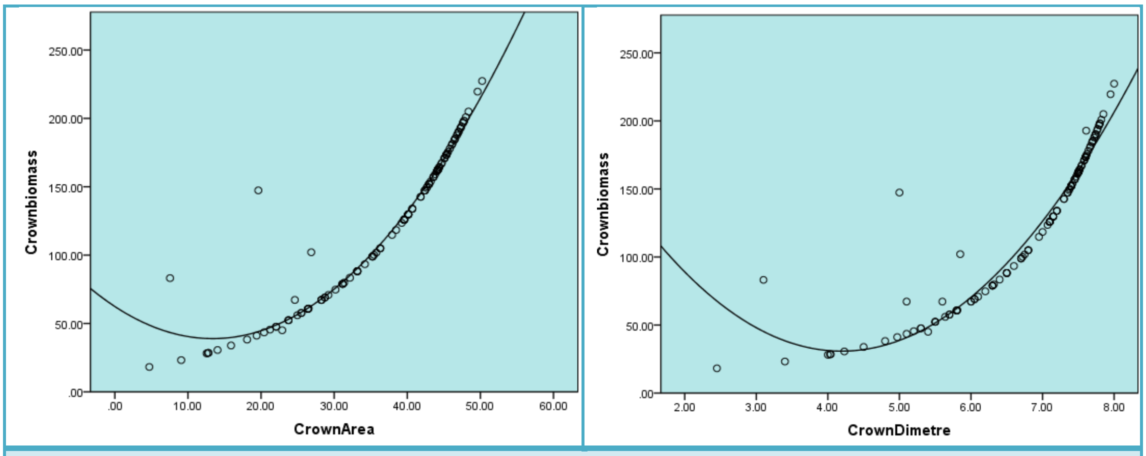


Figure 4.3 : Correlation between crown area and crown diameter with crown biomass

4.4.2 Trunk Biomass

The correlation relationship with field parameter have been tested and the result presented in the following (figure 4.4).

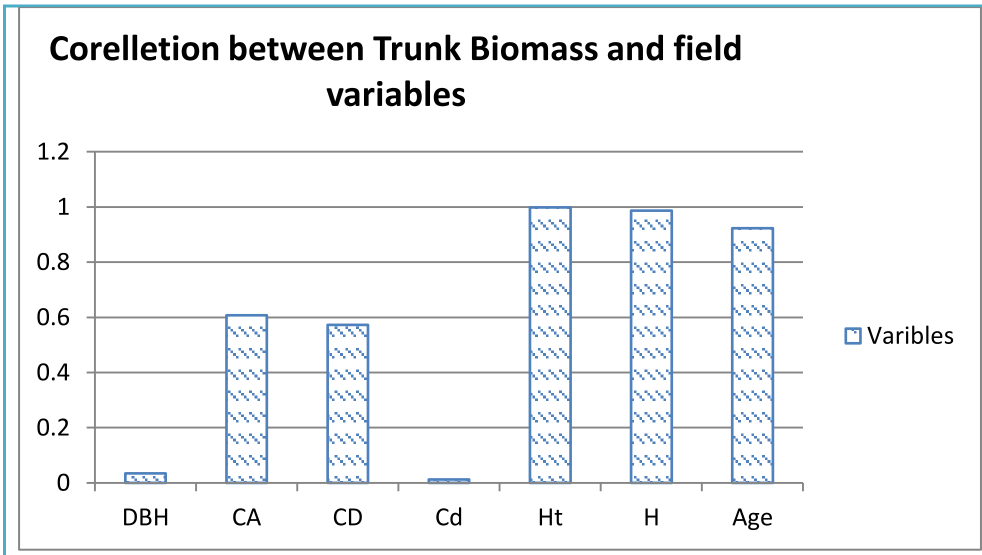


Figure 4. 4: Correlation relationship between field variables and trunk biomass

We found that except for DBH, Cd, have not a significant correlation at the level of significance (α<0.05) with trunk biomass, for rest variables (H, Ht) have a high positive correlation (0.987, 0.999), while (CA, CD) showed intermediate correlation with biomass (0.607, 0.573). Furthermore the result of the standardized regression test (in table 4.13) show that only height of trunk has a significant relationship (positive effect) at the level of significance (α<0.05) with Beta = 1.00.

Table 4.13 : Regression relationship for trunk biomass with field variables

Depends	Predictors Variable	Beta	Sig	R^2	Optimal Regression Equation
Trunk Biomass	DBH	-0.001	0.733	0.999	Y=e^ (5.586 – 28.736/ X)
	Cd	-0.001	0.905		Y=8.141+(630.058*X)+(-1.322*X³)
	CD	0.007	0.742		Y= 0.607*(2.182 ^ X)
	CA	-0.011	0.622		Y=9.193*(1.073 ^ X)
	Ht	1.003	0.000		Y=-2.402+(47.359*X)* Y=-0.917+(46.390*X)+(0.108*X²)
	H	-0.010	0.733		Y=92.134+(-43.774*X)+(10.360*X²)+(-0.367*X³)
	Fronds	0.007	0.302		Y=49.745+(-4.940*X)+(0.261*X²)+(-0.002*X³)
	Age	0.004	0.683		Y=142.707+(-198.223*X)+(83.060*X²)

Enter Method, *: stepwise Method

As shown in previous (table 4.13) trunk height is the best indicators for trunk biomass estimation with a coefficient of determination (R^2 = 0. 999, P< 0.05) with quadratic model _polynomial regression equation (2nd order)_, this corresponds to Issa.S, et al, 2018 study but is inconsistent with Khalid ,et al ,1999 who use the total height for estimation the AGB of oil palm tree.

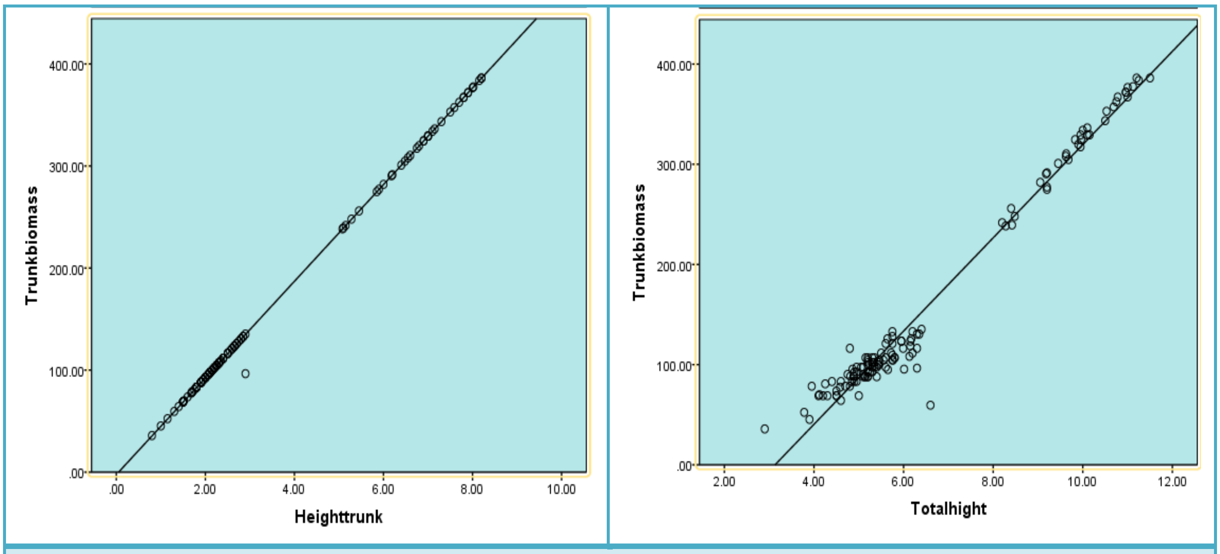


Figure 4.5: The correlation between total high and height trunk with trunk biomass

Despite the total height of the trunk has a high correlation with trunk biomass, but the right curve of regression is evidenced it can't be an exemplification relation for trunk biomass estimation, this makes the result more meaningful, due to the trunk of the Date Palm tree has different growth characters, while Holopainen. M, et al, 2011 reported that the stem diameter decreases with increasing growth.

4.4.3 AGB Equation

The main components of AGB (Trunk Biomass, Crown Biomass) have a high positive correlation with it (0.923, 0.857), in addition to the correlation of age with a value 0.850. Issa.S, et al, 2018 selected a standard equation for calculating the above ground biomass, which was depended in our mathematical calculating, to confirm the interrelationship for own Date Palm varieties a Standardized Multi Regression Test for the component of AGB and age have been done as presented in following (table 4.14)

Table 4. 14: Regression equations for estimation AGB

Depends	Predictors Variable	Beta	Sig	R^2	Regression Equation
AGB	Trunk Biomass	0.741	0.000	0.994	-2.235 + (1.016 * X1)+(0.985* X2)
	Crown Biomass	0.335	0.000		
Enter Method	**X1: Trunk Biomass , X2 : Crown Biomass**				

Both variables have a significant relationship at the level of significance (α<0.05) with AGB and a high coefficient of determination ($R^2 = 0.994$, $P < 0.05$). In (table4.14) simple linear equation was presented, while we note trunk biomass has a higher Beta value (0.741) which related to being the most important indicators for predicting AGB, the following figure represents the relationship between ABG and its components.

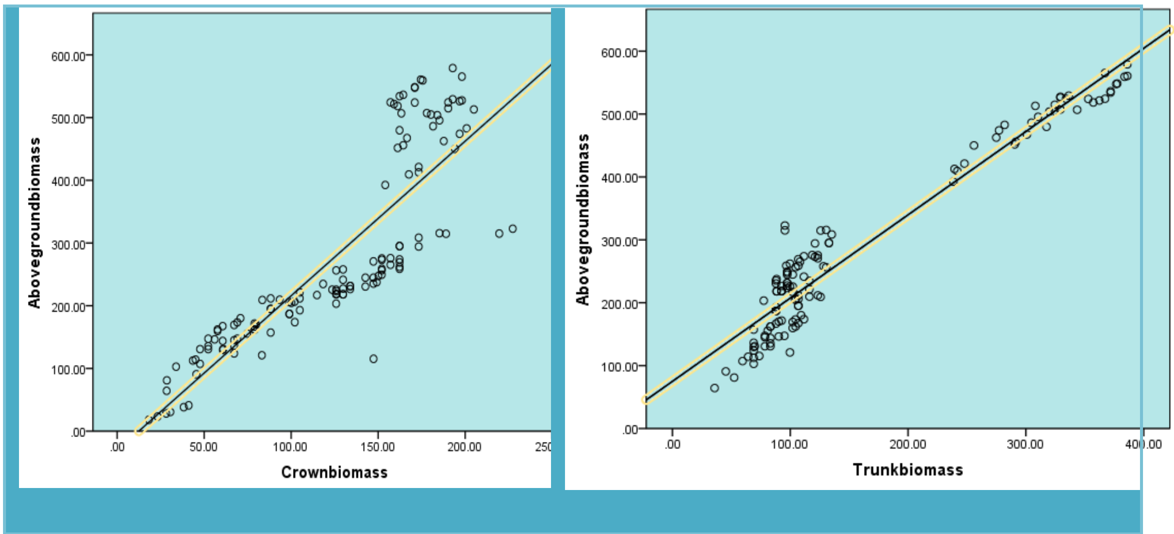


Figure 4.6 : Relationship between AGB and both components

Generally, we can't approve only one of the variable for estimation AGB, the indirect effect of age appear in both curves for estimation regression, by considered to figure, it is observed that the representative points of crown biomass are closely from the straight line at beginning of growth, then moves away from the line, on the contrary of trunk biomass, which their representative points are approaching more to the ending of a straight line, and this corresponds with preliminary result regarding biomass ratio relying on age (table 4.5). Furthermore, age has a significant relationship at the level of significance ($\alpha<0.05$) with AGB as shown in (table 4.15).

Table 4. 15: The effect of age on AGB estimation				
Depends	Factor	Beta	Sig	R^2
Above ground biomass	Age	0.921	0.000	0.847

According to this result with a value of Beta = 0.921 and coefficient of determination R^2 = 0.874 which refer to the percentage of Date Palm tree which their AGB effect by age, therefore we have to take the age factor into account when developing an optimal mathematical equation for estimation AGB.

The represented relationship for growth of AGB component according the class of age has been presented in the following figure

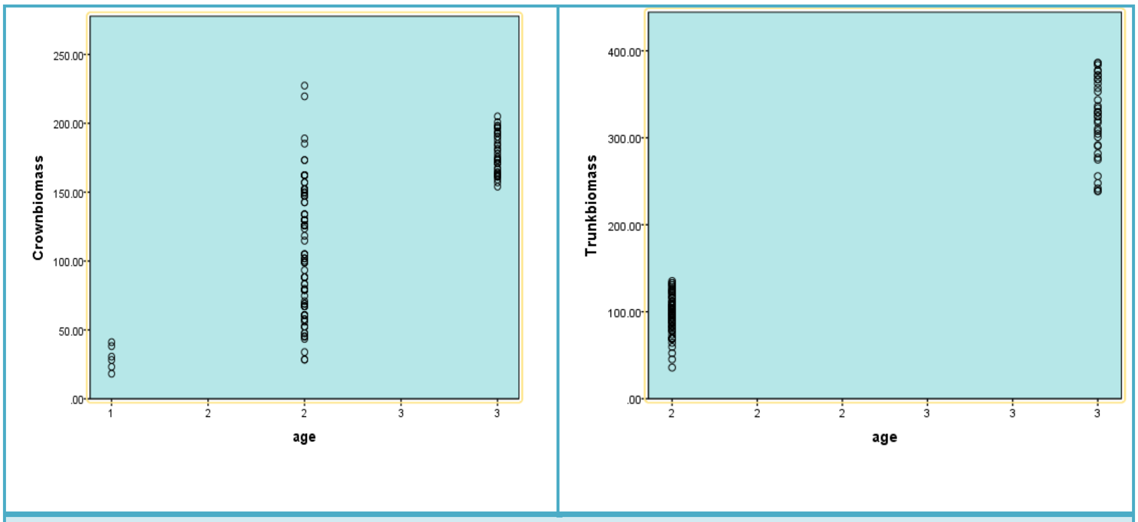


Figure 4.7 : The development of AGB components according to age

Age 1: Young – Age 2: Medium – Age 3: Mature

It is clear that crown biomass is more affecting than trunk biomass at medium age while the trunk biomass has a higher concentration at mature class than crown biomass. Ultimately it's imperative to identify specific equations for each class to estimate the above ground biomass rightly, while Korom.A, et al , 2016 confirm that the structural characteristics of the tree are developed with age but didn't study the regression relationship of tree structure parameters in each age phase.

4.5 AGB Equation Development

4.5.1 AGB Equation For Medium Tree

The field data fit with age classes and have a normal distribution, this enables us to build a specific equation for each one, only young palm tree AGB is equal crown biomass, while the medium and mature tree has a variance in components contribution to above-ground biomass. The following result presented the optimal regression equation between above ground date palm biomass and its components for medium and mature age classes.

Table 4.16 : Standardize Regression Test for Medium Tree

Depends	Predictors Variable	Beta	Sig	R^2	Regression Equation
AGB	Crown Biomass	0.929	0.000	0.864	Y= 67.039+ (1.248* X)
	Crown Biomass	0.718	0.000	0.951	-7.733 + (0.965* X1+ 1.096*X2)
	Trunk Biomass	0.364	0.000		

The crown biomass is the most influence indicator to predicting the AGB for a tree in the medium phase, simple regression by the stepwise method presented the linear relation in the previous table, but we found from the curve estimation that the quadratic regression equation is the most optimal model for estimating the relationship between crown biomass and AGB with a coefficient of determination (R^2 = 0.869, P < 0.05) as the following equation.

$$AGB = 45.755 + (1.692 * Crown\ Biomass) + (-0.002 * Crown\ Biomass^2)$$

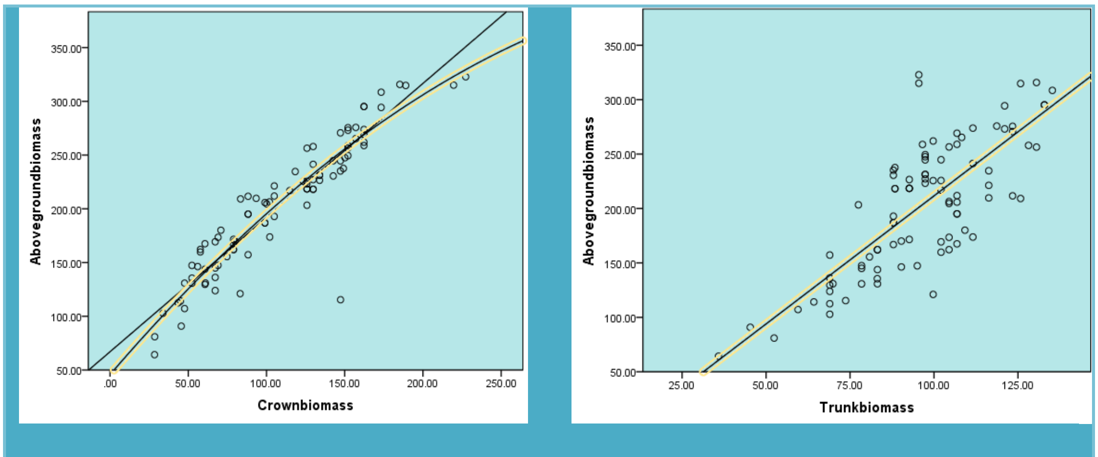


Figure 4 .8: correlation relationship for medium AGB components

Modification of Crown Biomass Equation

To achieve more accuracy in the result, the standard equation of crown biomass was developed to predict AGB for medium Date Palm tree as shown in (table 4.17).

Table 4.17 : Result of Standardized Regression Test for Crown Biomass

Depends	Predictors Variable	Beta	Sig	R^2	Regression Equation
Crown Biomass	Crown Area	0.898	0.000	0.898	Y= -45.065+(4.454*X)
	Crown Area	2.580	0.000	0.929	189+(12.790*X1) + (-79.660* X2)
	Crown Diameter	-1.689	0.000		
Stepwise Method					

We observed that crown area is the strong affecting indicator to crown biomass with Beta = 0.898, furthermore, the cubic model showed the best equation with a coefficient of determination (R^2 = 0.927, P < 0.05)

$$Crown\ Biomass = 81.634 + (-3.294 * CA) + (0.072 * CA^2) + (0.001 * CA^3)$$

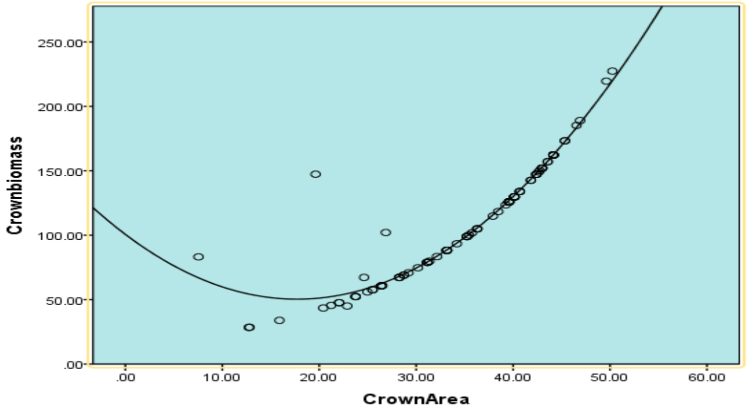


Figure 4.9 :Regression relationship between crown area and crown biomass for medium Date Palm tree

4.5.2 AGB Equation for Mature Tree

For mature Date Palm tree, trunk biomass has a significant relationship (effect) at the level of significance (α<0.05) with Beta = 0.975 comparison to crown biomass (Beta= 0.316), which mean it is the best indicator for prediction AGB (table4.18).

Table 4.18 : Result of Multiple Regression Test for AGB

Depends	Predictors Variable	Beta	Sig	R^2	Regression Equation

AGB	Trunk Biomass	0.949	0.000	0.901	Y= 186.537 +(0.973*X)
	Trunk Biomass	0.975	0.000	0.997	Y= 0.002 + (1*X1)+(1*X2)
	Crown Biomass	0.316	0.000		
Stepwise Method					

Furthermore, the curve estimation of the best relationship in (Figure 4.8) shows the linear equation is the most optimal model to estimate AGB for mature date palm tree with a coefficient of determination (R^2 = 0.901, P < 0.05) as the following equation

*AGB = 186.537 + (Trunk Biomass * 0.973)*

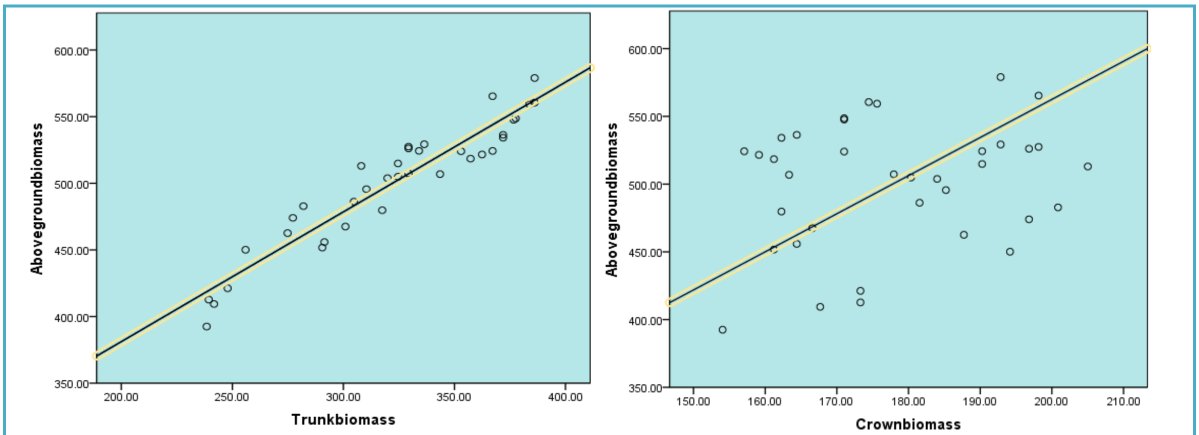


Figure 4.10: Correlation relationship for mature AGB components

The development of a new equation for estimating mature AGB which depending on trunk biomass requires a modification in a component of the trunk biomass equation (Ht) especially because it's own a statistically significant correlation relationship at the level of significance (α<0.05) with high positive value = 0.928.

The result of regression analysis in (appendix 4.4) shows that the simple linear equation with a coefficient of determination (R^2 = 1.000 , P < 0.05) is the optimal model for estimation the trunk biomass of mature date palm tree as shown in (figure 4.9).

*Trunk Biomass = (47.335 * Ht) - 2.034*

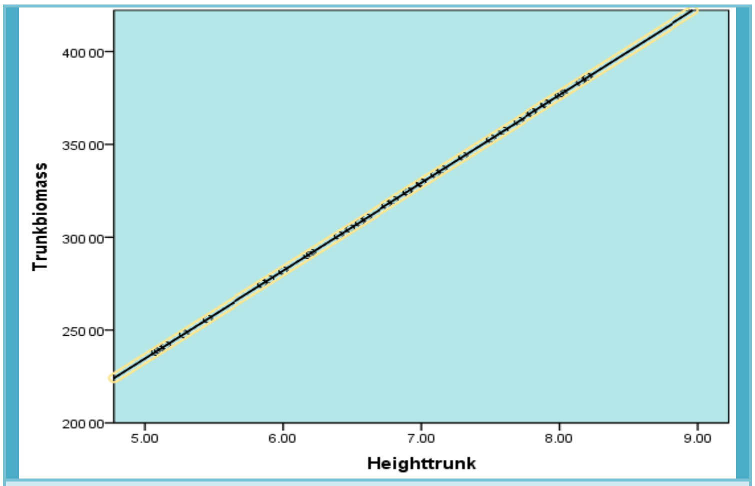


Figure 4.11: Regression relationship between the height of trunk and crown biomass for mature Date Palm tree

4.5.3 Estimation AGB from measurement directly

Sheriff.R, et, al, 2012 biased the, found that the (H total height)can be used directly to found the fresh volume of oil palm, and this corresponds with our result related to the mature tree as the following equation

$$AGB = -130.291 + (63.261 * H)$$

For medium Date Palm tree, the crown area is the best parameters as equation

$$AGB = -15.312 + (6.313 * CA)$$

4.6 Internal Validation

The objective of this section is to validate the performance of our models in AGB estimation by providing an examples form from the collected data, (appendix 4.5).

4.6.1 Validation of AGB estimation

Indiscriminate samples from raw data within different age class were selected for application of the developed equations in (table 4.22), and the result confirms that all the equations which used for estimating the components of AGB have identical results with the original value, but we detect that there is a tiny error in the medium and mature models which developed to estimate AGB by using one component, the crown biomass for medium tree and trunk biomass for a mature tree. Furthermore we have to realize the fact of adopting a specific form for each age class, reduces many of the difficult and costly field measurements as total height and crown diameter for mature trees, which need a hydraulic lift truck.

Table 4. 19 : Applied form of new equations for estimation AGB

Row Data			**Models**	**Factors**	**Equation**	**C.R**	**A.R**
CA	**Ht**	**Age**	General	Crown.B	$14.034*(1.057^{CA})$ *	162.27	162.27
44.16	2.40	7		Trunk.B	$-0.917+(46.39*Ht)+(0.108*Ht^2)$	111	111.57
			AGB = Crown.B + Trunk.B			273.3	273.84
			Medium	Crown.B	$81.634+(-3,294*CA)+(0.072*CA^2)+(0.001*CA^3)$	162.69	162.27
			AGB = $45.755+(1.692*CB)+(-0.002*CB^2)$			268	274
34.19	2.50	7	General	Crown.B	$14.034*(1.057^{CA})$ *	93.41	93.41
				Trunk.B	$-0.917+(46.39*Ht)+(0.108*Ht^2)$	115.7	116.30
			AGB = Crown.B + Trunk.B			209	210
			Medium	Crown.B	$81.634+(-3,294*CA)+(0.072*CA^2)+(0.001*CA^3)$	93.14	93.41
			AGB = $45.755+(1.692*CB)+(-0.002*CB^2)$			186	209
49.16	2.06	7	General	Crown.B	$14.034*(1.057^{CA})$ *	219.6	219.6
				Trunk.B	$-0.917+(46.39*Ht)+(0.108*Ht^2)$	95	95.5
			AGB = Crown.B + Trunk.B			314.6	315.1
			Medium	Crown.B	$81.634+(-3,294*CA)+(0.072*CA^2)+(0.001*CA^3)$	212.5	219.6
			AGB = $45.755+(1.692*CB)+(-0.002*CB^2)$			314.9	315.1
45.34	5.1	12	General	Crown.B	$14.034*(1.057^{CA})$ *	173.29	173.29
				Trunk.B	$-0.917+(46.39*Ht)+(0.108*Ht^2)$	235.6	239.4
			AGB = Crown.B + Trunk.B			408.89	412.67
			Mature	Trunk.B	$(47.335*Ht) - 2.034$	239.4	239.4

			AGB = 186.537 + (TB * 0.973)			419	412.67
45.28	7	12	General	Crown.B	14.034*(1.057^CA) *	177.95	177.95
				Trunk.B	-0.917+(46.39*Ht)+(0.108*Ht^2)	329.1	329.31
			AGB = Crown.B + Trunk.B			507	507.26
			Mature	Trunk.B	(47.335*Ht) – 2.034	329.31	329.31
			AGB = 186.537 + (TB * 0.973)			506.96	507.26
45.1	8	12	General	Crown.B	14.034*(1.057^CA) *	171.02	171.02
				Trunk.B	-0.917+(46.39*Ht)+(0.108*Ht^2)	377.1	376.65
			AGB = Crown.B + Trunk.B			548.14	547
			Mature	Trunk.B	(47.335*Ht) – 2.034	376.65	376.65
			AGB = 186.537 + (TB * 0.973)			553	547
C.R: Calculated Result			A.R: Actually Result	CB: Crown Biomass	TB: Trunk Biomass	AGB: Above ground biomass	
***: The equation is quite similar to that used in the methodology (3.2.2.1.2).**							

Chapter . 5

Conclusions & Recommendations

5.1 Conclusions

This Chapter review the most important findings that are reached and then suggested recommendations to improve Date Palm sector management.

The main purpose of this research was to develop new models for estimation of above-ground biomass (AGB) for Date Palm trees in the Jordan Valley region, in addition, to detecting which variables have the most effect on AGB.

- It has been found that within the same age group (medium phase), the only crown area has a high variance within varieties that refer to Degla-Nour, despite the residual parameters are statistically significant, just for the DBH parameter Berhi exceed the Degla-Nour, which mean that the DBH hasn't a statistically significant effect for AGB accumulation, moreover, Degla-Nour has the ability in accumulation of AGB more than other varieties and in total biomass followed by Berhi while Medjool has the lowest value, this indicates that crown area is the most factor affecting AGB accumulation for the tree at medium phase. In contrast of trees at mature phase, the height of trunk and total height has an over percentage in growth than there for a crown area within the same variety group (Medjool) hence have the major affecting AGB accumulation.

- AGB model was constructed using the most common linear form with both components (crown, trunk) biomass, this information is leading to the conclusion that the fundamental importance of successful model construction is the strength of the model fit to available independent variables according to R value, therefore, in some later models, the nonlinear models were preferred to use accordingly to R value. While considering the result that confirm the effect of age on biomass ($R^2 = 0.847$), we can divide the models constructed for AGB estimation as the following
- In case when age is unknown, it is recommended to use the equation combine with both types, a model was developed for estimation (crown, trunk) biomass as follow

$$AGB = Crown\ Biomass + Trunk\ Biomass$$

Whereas

$$Crown\ biomass = 14.034 * (1.057 \wedge CA)$$

$$Trunk\ Biomass = -0.917 + (46.390 * Ht) + (0.108 * Ht^2)$$

- For medium Date Palm tree we can conclude that the crown biomass is sufficiently robust to be applied to estimate above-ground biomass for medium Date Palm tree as the following

  $$AGB = 45.755 + (1.692 * \text{Crown Biomass}) + (-0.002 * \text{Crown Biomass}^2)$$

  Furthermore, the cubic model is the best form (R^2= 0.927) to constructing an equation to measure Crown Biomass for medium Date Palm trees

  $$\text{Crown Biomass} = 81.634 + (-3.294 * \text{CA}) + (0.072 * \text{CA}^2) + (0.001 * \text{CA}^3)$$

- As for the mature Date Palm tree, trunk biomass is sufficiently robust to be applied for estimation above-ground biomass as the following equation

  AGB = 186.537 + (Trunk Biomass * 0.973)

  To achieve more accuracy, we concluded to implement the next equation for measuring their Trunk Biomass with (R^2 = 1)

  Trunk Biomass = (47.335 * Ht) - 2.034

- Above-ground biomass can be estimated directly by field parameters (Total height and Crown Area) as follow

  For Medium Date Palm tree : $AGB = -15.312 + (6.313 * CA)$

  For Mature Date Palm tree : $AGB = -130.291 + (63.261 * H)$

5.2 Recommendations

- During the study and depending on the previous conclusions, some of the ideas can be developed and recommendations for the sector employees and future research of above-ground biomass in the Jordan Valley region.

- It is recommended to conduct validation experiments for updated models related to estimate AGB.

- It is recommended to adopt the outputs of this research and develop models estimation with observance to study tree sampling from multiple sites to increases accuracy in models generalization.

- For future research, the integration between using remote sensing technique as satellite imagery and field measurement which adopts our models will give more accurate result in biomass estimated.

- This study recommends the future studies take a research point about varieties that have more potential in developing above-ground biomass accumulating at mature phase, hence the maximum amount of carbon store, whereas this relationship was not ready to comparison when the study was conducted.

- Developing AGB maps in the region and studying the environmental impact of Date Palm cultivation in carbon storage, due to its there in the most sensitive area for climate change.

- It is proposed to exclude the parameter of crown depth from field measurement in future research.

- It is recommended to farmers and investors pay more attention to agricultural practices which improve soil quality and recover their fertility.

- It is proposed to limit the use of parameters measurement directly in estimation AGB, which depend on the total height of the tree because of the difficulty of manually measure and there is a possibility of making an error which reflecting in AGB measurement.

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Appendix 3. 1 : Field Design

N

Date Palm varieties field, 2015

Medjool Field 2009- 2010

W | E

Internal Street	M 36	M, 25	M, 24	M, 13	M, 12	M, 1	**Medjool field 2009 - 2010**
	M 35	M, 26	M, 23	M, 14	M, 11	M, 2	
	M 34	M, 27	M, 22	M, 15	M, 10	M, 3	
	M 33	M, 28	M, 21	M, 16	M, 9	M, 4	
	M 32	M, 29	M, 20	M, 17	M, 8	M, 5	
	M 31	M 30	M, 19	M, 18	M, 7	M, 6	

S

M : Medjool

Date Palm varieties field, 2015

N

W

D F6	D E5	D D6	D C5	D B6	D A6		B F6	B E6	B D6	B C6	B B6	B A6		M F6	M E6	M D6	M C6	M B6	M A6
D F5	D E5	D D5	D C5	D B5	D A5		B F5	B E5	B D5	B C5	B B5	B A5		M F5	M E5	M D5	M C5	M B5	M A5
D F4	D E4	D D4	D C4	D B4	D A4		B F4	B E4	B D4	B C4	B B4	B A4		M F4	M E4	M D4	M C4	M B4	M A4
D F3	D E3	D D3	D C3	D B3	D A3		B F3	B E3	B D3	B C3	B B3	B A3		M F3	M E3	M D3	M C3	M B3	M A3
D F2	D E2	D D2	D C2	D B2	D A2		B F2	B E2	B D2	B C2	B B2	B A2		M F2	M E2	M D2	M C2	M B2	M A2
D F1	D E1	D D1	D C1	D B1	D A1		B F1	B E1	B D1	B C1	B B1	B A1		M F1	M E1	M D1	M C1	M B1	M A1

E

S

M : Medjool
B : Berhi
D : Degla-Nour

JSAR Field

Appendix 4.1 : Normal Distribution

Explore

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Variety	128	69.2%	57	30.8%	185	100.0%
Age	128	69.2%	57	30.8%	185	100.0%
Clusters	128	69.2%	57	30.8%	185	100.0%
Fronds	128	69.2%	57	30.8%	185	100.0%
Crownbiomass	128	69.2%	57	30.8%	185	100.0%
Trunkbiomass	128	69.2%	57	30.8%	185	100.0%
Abovegroundbiomass	128	69.2%	57	30.8%	185	100.0%
Belowgroundbiomass	128	69.2%	57	30.8%	185	100.0%
Totalbiomass	128	69.2%	57	30.8%	185	100.0%
DBH	128	69.2%	57	30.8%	185	100.0%
CrownDimetre	128	69.2%	57	30.8%	185	100.0%
Crowndepth	128	69.2%	57	30.8%	185	100.0%
CrownArea	128	69.2%	57	30.8%	185	100.0%
Heighttrunk	128	69.2%	57	30.8%	185	100.0%
Totalhight	128	69.2%	57	30.8%	185	100.0%

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Variety	.323	128	.000	.747	128	.000
Age	.452	128	.000	.563	128	.000
Clusters	.088	128	.018	.988	128	.345
Fronds	.187	128	.000	.898	128	.000
Crownbiomass	.124	128	.000	.953	128	.000
Trunkbiomass	.312	128	.000	.756	128	.000
Abovegroundbiomass	.187	128	.000	.880	128	.000
Belowgroundbiomass	.097	128	.005	.964	128	.002
Totalbiomass	.113	128	.000	.934	128	.000
DBH	.119	128	.000	.956	128	.000
CrownDimetre	.200	128	.000	.854	128	.000
Crowndepth	.115	128	.000	.958	128	.001

CrownArea	.180	128	.000	.893	128	.000
Heighttrunk	.313	128	.000	.759	128	.000
Totalhight	.243	128	.000	.831	128	.000

a. Lilliefors Significance Correction

Appendix 4.2 : Pearson Correlations

Correlations

Notes

Output Created		09-FEB-2021 20:00:48
Comments		
Input	Data	C:\Users\2021\Desktop\Untitled2_1.sav تعديل النهائي للكتلة.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	185
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.

Syntax		CORRELATIONS /VARIABLES=Variety age Clusters Fronds Crownbiomass Trunkbiomass Abovegroundbiomass Belowgroundbiomass Totalbiomass DBH CrownDimetre Crowndepth CrownArea Heighttrunk Totalhight /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.23
	Elapsed Time	00:00:00.30

Correlations

		Variety	age	Clusters	Fronds	Crownbiomass	Trunkbiomass
Variety	Pearson Correlation	1	-.366-**	.428**	-.221-*	.170	-.409-**
	Sig. (2-tailed)		.000	.000	.011	.050	.000
	N	134	134	133	133	134	134
Age	Pearson Correlation	-.366-**	1	.347**	.882**	.690**	.923**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	134	134	133	133	134	134
Clusters	Pearson Correlation	.428**	.347**	1	.461**	.573**	.316**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	133	133	133	133	133	133

Fronds	Pearson Correlation	-.221-*	.882**	.461**	1	.702**	.855**
	Sig. (2-tailed)	.011	.000	.000		.000	.000
	N	133	133	133	133	133	133
Crownbiomass	Pearson Correlation	.170	.690**	.573**	.702**	1	.694**
	Sig. (2-tailed)	.050	.000	.000	.000		.000
	N	134	134	133	133	134	134
Trunkbiomass	Pearson Correlation	-.409-**	.923**	.316**	.855**	.694**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	134	134	133	133	134	134
Abovegroundbiomass	Pearson Correlation	-.231-**	.910**	.433**	.865**	.857**	.966**
	Sig. (2-tailed)	.007	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134
Belowgroundbiomass	Pearson Correlation	.347**	.533**	.661**	.630**	.916**	.556**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134
Totalbiomass	Pearson Correlation	-.136-	.879**	.492**	.859**	.903**	.932**
	Sig. (2-tailed)	.117	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134
DBH	Pearson Correlation	.315**	.170*	.452**	.253**	.505**	.140
	Sig. (2-tailed)	.000	.049	.000	.003	.000	.108
	N	134	134	133	133	134	134

CrownDimetre	Pearson Correlation	.274**	.639**	.590**	.672**	.927**	.591**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134
Crowndepth	Pearson Correlation	.264**	.177*	.355**	.241**	.378**	.116
	Sig. (2-tailed)	.002	.041	.000	.005	.000	.183
	N	134	134	133	133	134	134
CrownArea	Pearson Correlation	.255**	.660**	.599**	.690**	.964**	.629**
	Sig. (2-tailed)	.003	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134
Heighttrunk	Pearson Correlation	-.405-**	.923**	.322**	.854**	.697**	1.000**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134
Totalhight	Pearson Correlation	-.360-**	.928**	.360**	.872**	.725**	.985**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	134	134	133	133	134	134

Correlations

		Abovegroundbiomass	Belowgroundbiomass	Totalbiomass	DBH	CrownDimetre
Variety	Pearson Correlation	-.231-**	.347**	-.136-	.315**	.274**
	Sig. (2-tailed)	.007	.000	.117	.000	.001
	N	134	134	134	134	134

Age	Pearson Correlation	.910**	.533**	.879**	.170*	.639**
	Sig. (2-tailed)	.000	.000	.000	.049	.000
	N	134	134	134	134	134
Clusters	Pearson Correlation	.433**	.661**	.492**	.452**	.590**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
	N	133	133	133	133	133
Fronds	Pearson Correlation	.865**	.630**	.859**	.253**	.672**
	Sig. (2-tailed)	.000	.000	.000	.003	.000
	N	133	133	133	133	133
Crownbiomass	Pearson Correlation	.857**	.916**	.903**	.505**	.927**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
	N	134	134	134	134	134
Trunkbiomass	Pearson Correlation	.966**	.556**	.932**	.140	.591**
	Sig. (2-tailed)	.000	.000	.000	.108	.000
	N	134	134	134	134	134
Abovegroundbiomass	Pearson Correlation	1	.728**	.992**	.282**	.757**
	Sig. (2-tailed)		.000	.000	.001	.000
	N	134	134	134	134	134
Belowgroundbiomass	Pearson Correlation	.728**	1	.808**	.672**	.924**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	134	134	134	134	134

Totalbiomass	Pearson Correlation	.992**	.808**	1	.365**	.819**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	134	134	134	134	134
DBH	Pearson Correlation	.282**	.672**	.365**	1	.595**
	Sig. (2-tailed)	.001	.000	.000		.000
	N	134	134	134	134	134
CrownDimetre	Pearson Correlation	.757**	.924**	.819**	.595**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	134	134	134	134	134
Crowndepth	Pearson Correlation	.219*	.513**	.282**	.584**	.497**
	Sig. (2-tailed)	.011	.000	.001	.000	.000
	N	134	134	134	134	134
CrownArea	Pearson Correlation	.798**	.940**	.856**	.581**	.991**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
	N	134	134	134	134	134
Heighttrunk	Pearson Correlation	.966**	.559**	.933**	.143	.594**
	Sig. (2-tailed)	.000	.000	.000	.100	.000
	N	134	134	134	134	134
Totalhight	Pearson Correlation	.966**	.609**	.941**	.221*	.642**
	Sig. (2-tailed)	.000	.000	.000	.010	.000
	N	134	134	134	134	134

Correlations

		Crowndepth	CrownArea	Heighttrunk	Totalhight
Variety	Pearson Correlation	.264**	.255**	-.405-**	-.360-**
	Sig. (2-tailed)	.002	.003	.000	.000
	N	134	134	134	134
Age	Pearson Correlation	.177*	.660**	.923**	.928**
	Sig. (2-tailed)	.041	.000	.000	.000
	N	134	134	134	134
Clusters	Pearson Correlation	.355**	.599**	.322**	.360**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	133	133	133	133
Fronds	Pearson Correlation	.241**	.690**	.854**	.872**
	Sig. (2-tailed)	.005	.000	.000	.000
	N	133	133	133	133
Crownbiomass	Pearson Correlation	.378**	.964**	.697**	.725**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	134	134	134	134
Trunkbiomass	Pearson Correlation	.116	.629**	1.000**	.985**
	Sig. (2-tailed)	.183	.000	.000	.000
	N	134	134	134	134
Abovegroundbiomass	Pearson Correlation	.219*	.798**	.966**	.966**
	Sig. (2-tailed)	.011	.000	.000	.000
	N	134	134	134	134
Belowgroundbiomass	Pearson Correlation	.513**	.940**	.559**	.609**
	Sig. (2-tailed)	.000	.000	.000	.000

	N	134	134	134	134
Totalbiomass	Pearson Correlation	.282**	.856**	.933**	.941**
	Sig. (2-tailed)	.001	.000	.000	.000
	N	134	134	134	134
DBH	Pearson Correlation	.584**	.581**	.143	.221*
	Sig. (2-tailed)	.000	.000	.100	.010
	N	134	134	134	134
CrownDimetre	Pearson Correlation	.497**	.991**	.594**	.642**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	134	134	134	134
Crowndepth	Pearson Correlation	1	.459**	.118	.256**
	Sig. (2-tailed)		.000	.173	.003
	N	134	134	134	134
CrownArea	Pearson Correlation	.459**	1	.631**	.672**
	Sig. (2-tailed)	.000		.000	.000
	N	134	134	134	134
Heighttrunk	Pearson Correlation	.118	.631**	1	.985**
	Sig. (2-tailed)	.173	.000		.000
	N	134	134	134	134
Totalhight	Pearson Correlation	.256**	.672**	.985**	1
	Sig. (2-tailed)	.003	.000	.000	
	N	134	134	134	134

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 4.3: One way ANOVA & Tukey Analyses

Means

Report

Clusters

Variety	Mean	N	Std. Deviation	Minimum	Maximum
Medjool	7.63	30	3.653	0	14
Berhi	9.97	36	3.121	3	16
Degla- Nour	15.15	26	3.016	9	21
Total	10.67	92	4.413	0	21

Mean

Report

Crownbiomass

Variety	Mean	N	Std. Deviation	Minimum	Maximum
Medjool	67.4488	30	24.31264	28.55	147.35
Berhi	119.6900	36	40.33336	28.44	227.36
Degla- Nour	142.8776	26	29.84118	74.76	188.99
Total	109.2079	92	44.73200	28.44	227.36

Oneway

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Clusters	Medjool	30	7.63	3.653	.667	6.27	9.00	0	14
	Berhi	36	9.97	3.121	.520	8.92	11.03	3	16
	Degla-Nour	26	15.15	3.016	.591	13.94	16.37	9	21
	Total	92	10.67	4.413	.460	9.76	11.59	0	21
Fronds	Medjool	30	32.03	4.930	.900	30.19	33.87	25	45
	Berhi	36	30.25	5.288	.881	28.46	32.04	14	43
	Degla-Nour	26	37.46	6.269	1.229	34.93	39.99	25	50
	Total	92	32.87	6.186	.645	31.59	34.15	14	50
Crownbiomass	Medjool	30	67.4488	24.31264	4.43886	58.3703	76.5273	28.55	147.35
	Berhi	36	119.6900	40.33336	6.72223	106.0432	133.3369	28.44	227.36
	Degla-Nour	26	142.8776	29.84118	5.85234	130.8245	154.9307	74.76	188.99
	Total	92	109.2079	44.73200	4.66363	99.9441	118.4716	28.44	227.36
Trunkbiomass	Medjool	30	89.6370	21.44096	3.91456	81.6308	97.6432	45.30	125.77
	Berhi	36	92.9521	16.39632	2.73272	87.4044	98.4998	35.83	130.50
	Degla-Nour	26	109.3359	17.05397	3.34456	102.4477	116.2242	80.80	135.24

	Total	92	96.5013	19.93452	2.07832	92.3730	100.6296	35.83	135.24
Abovegroundbiomass	Medjool	30	149.9047	37.11830	6.77684	136.0445	163.7649	80.95	211.64
	Berhi	36	212.6414	50.55903	8.42651	195.5347	229.7481	64.27	322.83
	Degla-Nour	26	252.2135	43.92856	8.61510	234.4704	269.9566	155.56	315.73
	Total	92	203.3672	60.08643	6.26444	190.9236	215.8107	64.27	322.83
Belowgroundbiomass	Medjool	30	74.3639	18.40922	3.36105	67.4898	81.2380	40.15	104.97
	Berhi	36	105.4701	25.07728	4.17955	96.9852	113.9551	31.88	160.13
	Degla-Nour	26	125.0979	21.78856	4.27309	116.2973	133.8985	77.16	156.60
	Total	92	100.8738	29.79931	3.10679	94.7025	107.0450	31.88	160.13
Totalbiomass	Medjool	30	224.2777	55.51958	10.13644	203.5463	245.0090	121.11	316.62
	Berhi	36	318.1108	75.63608	12.60601	292.5193	343.7024	96.15	482.96
	Degla-Nour	26	377.3112	65.71684	12.88813	350.7675	403.8548	232.72	472.33
	Total	92	304.2436	89.88126	9.37077	285.6297	322.8575	96.15	482.96
DBH	Medjool	30	50.4643	8.22042	1.50084	47.3948	53.5339	35.03	65.28
	Berhi	36	58.3611	12.95204	2.15867	53.9788	62.7435	28.66	79.61
	Degla-Nour	26	57.6823	4.59761	.90167	55.8253	59.5393	46.17	65.28

	Total	92	55.5942	10.23784	1.06737	53.4740	57.7144	28.66	79.61
CrownDimetre	Medjool	30	5.5993	.77416	.14134	5.3103	5.8884	3.10	6.70
	Berhi	36	6.8781	.70790	.11798	6.6385	7.1176	4.03	8.00
	Degla-Nour	26	7.2508	.40557	.07954	7.0870	7.4146	6.20	7.73
	Total	92	6.5664	.95366	.09943	6.3689	6.7639	3.10	8.00
Crowndepth	Medjool	30	3.0173	.34830	.06359	2.8873	3.1474	2.25	3.60
	Berhi	36	3.1636	.35587	.05931	3.0432	3.2840	2.10	3.95
	Degla-Nour	26	3.2104	.30431	.05968	3.0875	3.3333	2.50	3.80
	Total	92	3.1291	.34538	.03601	3.0576	3.2007	2.10	3.95
CrownArea	Medjool	30	25.3279	6.25834	1.14261	22.9910	27.6648	7.54	35.24
	Berhi	36	37.5187	6.96674	1.16112	35.1615	39.8759	12.74	50.24
	Degla-Nour	26	41.3945	4.42422	.86766	39.6075	43.1815	30.18	46.91
	Total	92	34.6388	9.02371	.94079	32.7700	36.5075	7.54	50.24
Heighttrunk	Medjool	30	1.9367	.45295	.08270	1.7675	2.1058	1.00	2.70
	Berhi	36	2.0067	.34639	.05773	1.8895	2.1239	.80	2.80
	Degla-Nour	26	2.3842	.37127	.07281	2.2343	2.5342	1.75	2.90
	Total	92	2.0905	.42969	.04480	2.0016	2.1795	.80	2.90
Totalhight	Medjool	30	5.0423	.68005	.12416	4.7884	5.2963	3.78	6.60
	Berhi	36	5.1703	.65646	.10941	4.9482	5.3924	2.90	6.30
	Degla-Nour	26	5.5946	.56874	.11154	5.3649	5.8243	4.25	6.40

Total	92	5.2485	.67279	.07014	5.1091	5.3878	2.90	6.60

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Clusters	Between Groups	816.894	2	408.447	38.052	.000
	Within Groups	955.324	89	10.734		
	Total	1772.217	91			
Fronds	Between Groups	816.257	2	408.128	13.624	.000
	Within Groups	2666.178	89	29.957		
	Total	3482.435	91			
Crownbiomass	Between Groups	85744.904	2	42872.452	39.605	.000
	Within Groups	96341.728	89	1082.491		
	Total	182086.632	91			
Trunkbiomass	Between Groups	6149.975	2	3074.987	9.119	.000
	Within Groups	30012.051	89	337.214		
	Total	36162.025	91			
Abovegroundbiomass	Between Groups	150878.688	2	75439.344	37.791	.000
	Within Groups	177665.766	89	1996.245		
	Total	328544.454	91			
Belowgroundbiomass	Between Groups	37100.804	2	18550.402	37.774	.000
	Within Groups	43707.069	89	491.091		
	Total	80807.873	91			
Totalbiomass	Between Groups	337569.874	2	168784.937	37.783	.000

	Within Groups	397586.446	89	4467.263		
	Total	735156.319	91			
DBH	Between Groups	1178.440	2	589.220	6.273	.003
	Within Groups	8359.576	89	93.928		
	Total	9538.015	91			
CrownDimetre	Between Groups	43.731	2	21.865	49.857	.000
	Within Groups	39.032	89	.439		
	Total	82.762	91			
Crowndepth	Between Groups	.589	2	.295	2.555	.083
	Within Groups	10.266	89	.115		
	Total	10.855	91			
CrownArea	Between Groups	4085.968	2	2042.984	54.702	.000
	Within Groups	3323.921	89	37.347		
	Total	7409.889	91			
Heighttrunk	Between Groups	3.206	2	1.603	10.494	.000
	Within Groups	13.595	89	.153		
	Total	16.801	91			
Totalhight	Between Groups	4.610	2	2.305	5.608	.005
	Within Groups	36.581	89	.411		
	Total	41.191	91			

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Variety	(J) Variety	Mean	Std.	Sig.	95% Confidence Interval

			Difference (I-J)	Error		Lower Bound	Upper Bound
Clusters	Medjool	Berhi	-2.339-*	.810	.013	-4.27-	-.41-
		Degla-Nour	-7.521-*	.878	.000	-9.61-	-5.43-
	Berhi	Medjool	2.339*	.810	.013	.41	4.27
		Degla-Nour	-5.182-*	.843	.000	-7.19-	-3.17-
	Degla-Nour	Medjool	7.521*	.878	.000	5.43	9.61
		Berhi	5.182*	.843	.000	3.17	7.19
Fronds	Medjool	Berhi	1.783	1.353	.389	-1.44-	5.01
		Degla-Nour	-5.428-*	1.467	.001	-8.92-	-1.93-
	Berhi	Medjool	-1.783-	1.353	.389	-5.01-	1.44
		Degla-Nour	-7.212-*	1.409	.000	-10.57-	-3.85-
	Degla-Nour	Medjool	5.428*	1.467	.001	1.93	8.92
		Berhi	7.212*	1.409	.000	3.85	10.57
Crownbiomass	Medjool	Berhi	-52.24119-*	8.13340	.000	-71.6276-	-32.8548-
		Degla-Nour	-75.42874-*	8.81574	.000	-96.4415-	-54.4160-
	Berhi	Medjool	52.24119*	8.13340	.000	32.8548	71.6276
		Degla-Nour	-23.18755-*	8.46779	.020	-43.3710-	-3.0041-
	Degla-Nour	Medjool	75.42874*	8.81574	.000	54.4160	96.4415
		Berhi	23.18755*	8.46779	.020	3.0041	43.3710
Trunkbiomass	Medjool	Berhi	-3.31510-	4.53955	.746	-14.1353-	7.5051

		Degla-Nour	-19.69894-*	4.92039	.000	-31.4269-	-7.9709-
	Berhi	Medjool	3.31510	4.53955	.746	-7.5051-	14.1353
		Degla-Nour	-16.38385-*	4.72619	.002	-27.6489-	-5.1187-
	Degla-Nour	Medjool	19.69894*	4.92039	.000	7.9709	31.4269
		Berhi	16.38385*	4.72619	.002	5.1187	27.6489
Abovegroundbiomass	Medjool	Berhi	-62.73673-*	11.04503	.000	-89.0631-	-36.4103-
		Degla-Nour	-102.30885-*	11.97164	.000	-130.8439-	-73.7738-
	Berhi	Medjool	62.73673*	11.04503	.000	36.4103	89.0631
		Degla-Nour	-39.57213-*	11.49912	.003	-66.9809-	-12.1634-
	Degla-Nour	Medjool	102.30885*	11.97164	.000	73.7738	130.8439
		Berhi	39.57213*	11.49912	.003	12.1634	66.9809
Belowgroundbiomass	Medjool	Berhi	-31.10625-*	5.47824	.000	-44.1639-	-18.0486-
		Degla-Nour	-50.73402-*	5.93783	.000	-64.8871-	-36.5809-
	Berhi	Medjool	31.10625*	5.47824	.000	18.0486	44.1639
		Degla-Nour	-19.62777-*	5.70346	.003	-33.2223-	-6.0333-
	Degla-Nour	Medjool	50.73402*	5.93783	.000	36.5809	64.8871
		Berhi	19.62777*	5.70346	.003	6.0333	33.2223
Totalbiomass	Medjool	Berhi	-93.83317-*	16.52269	.000	-133.2158-	-54.4505-

		Degla-Nour	-153.03349-*	17.90884	.000	-195.7201-	-110.3469-
	Berhi	Medjool	93.83317*	16.52269	.000	54.4505	133.2158
		Degla-Nour	-59.20032-*	17.20199	.003	-100.2021-	-18.1985-
	Degla-Nour	Medjool	153.03349*	17.90884	.000	110.3469	195.7201
		Berhi	59.20032*	17.20199	.003	18.1985	100.2021
DBH	Medjool	Berhi	-7.89678-*	2.39584	.004	-13.6074-	-2.1862-
		Degla-Nour	-7.21797-*	2.59683	.018	-13.4077-	-1.0283-
	Berhi	Medjool	7.89678*	2.39584	.004	2.1862	13.6074
		Degla-Nour	.67880	2.49434	.960	-5.2666-	6.6242
	Degla-Nour	Medjool	7.21797*	2.59683	.018	1.0283	13.4077
		Berhi	-.67880-	2.49434	.960	-6.6242-	5.2666
CrownDimetre	Medjool	Berhi	-1.27872-*	.16371	.000	-1.6689-	-.8885-
		Degla-Nour	-1.65144-*	.17744	.000	-2.0744-	-1.2285-
	Berhi	Medjool	1.27872*	.16371	.000	.8885	1.6689
		Degla-Nour	-.37271-	.17044	.079	-.7790-	.0335
	Degla-Nour	Medjool	1.65144*	.17744	.000	1.2285	2.0744
		Berhi	.37271	.17044	.079	-.0335-	.7790
Crowndepth	Medjool	Berhi	-.14628-	.08396	.195	-.3464-	.0538
		Degla-Nour	-.19305-	.09100	.091	-.4100-	.0239

	Berhi	Medjool	.14628	.08396	.195	-.0538-	.3464
		Degla-Nour	-.04677-	.08741	.854	-.2551-	.1616
	Degla-Nour	Medjool	.19305	.09100	.091	-.0239-	.4100
		Berhi	.04677	.08741	.854	-.1616-	.2551
CrownArea	Medjool	Berhi	-12.19078-*	1.51074	.000	-15.7917-	-8.5899-
		Degla-Nour	-16.06655-*	1.63748	.000	-19.9696-	-12.1635-
	Berhi	Medjool	12.19078*	1.51074	.000	8.5899	15.7917
		Degla-Nour	-3.87577-*	1.57285	.041	-7.6247-	-.1268-
	Degla-Nour	Medjool	16.06655*	1.63748	.000	12.1635	19.9696
		Berhi	3.87577*	1.57285	.041	.1268	7.6247
Heighttrunk	Medjool	Berhi	-.07000-	.09662	.750	-.3003-	.1603
		Degla-Nour	-.44756-*	.10472	.000	-.6972-	-.1979-
	Berhi	Medjool	.07000	.09662	.750	-.1603-	.3003
		Degla-Nour	-.37756-*	.10059	.001	-.6173-	-.1378-
	Degla-Nour	Medjool	.44756*	.10472	.000	.1979	.6972
		Berhi	.37756*	.10059	.001	.1378	.6173
Totalhight	Medjool	Berhi	-.12794-	.15849	.700	-.5057-	.2498
		Degla-Nour	-.55228-*	.17178	.005	-.9617-	-.1428-
	Berhi	Medjool	.12794	.15849	.700	-.2498-	.5057
		Degla-Nour	-.42434-*	.16500	.031	-.8176-	-.0310-
	Degla-	Medjool	.55228*	.17178	.005	.1428	.9617

	Nour	Berhi	.42434*	.16500	.031	.0310	.8176

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Clusters

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05		
		1	2	3
Medjool	30	7.63		
Berhi	36		9.97	
Degla- Nour	26			15.15
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Fronds

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05	
		1	2
Berhi	36	30.25	
Medjool	30	32.03	
Degla- Nour	26		37.46

Sig.		.419	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Crownbiomass

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05		
		1	2	3
Medjool	30	67.4488		
Berhi	36		119.6900	
Degla- Nour	26			142.8776
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Trunkbiomass

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05	
		1	2

Medjool	30	89.6370	
Berhi	36	92.9521	
Degla- Nour	26		109.3359
Sig.		.764	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Abovegroundbiomass

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05		
		1	2	3
Medjool	30	149.9047		
Berhi	36		212.6414	
Degla- Nour	26			252.2135
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Belowgroundbiomass

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05		
		1	2	3
Medjool	30	74.3639		
Berhi	36		105.4701	
Degla- Nour	26			125.0979
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Totalbiomass

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05		
		1	2	3
Medjool	30	224.2777		
Berhi	36		318.1108	
Degla- Nour	26			377.3112
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

DBH

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05	
		1	2
Medjool	30	50.4643	
Degla- Nour	26		57.6823
Berhi	36		58.3611
Sig.		1.000	.960

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

CrownDimetre

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05	
		1	2
Medjool	30	5.5993	
Berhi	36		6.8781
Degla- Nour	26		7.2508
Sig.		1.000	.079

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Crowndepth

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05
		1
Medjool	30	3.0173
Berhi	36	3.1636
Degla- Nour	26	3.2104
Sig.		.076

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

CrownArea

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05		
		1	2	3
Medjool	30	25.3279		

Berhi	36		37.5187	
Degla- Nour	26			41.3945
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Heighttrunk

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05	
		1	2
Medjool	30	1.9367	
Berhi	36	2.0067	
Degla- Nour	26		2.3842
Sig.		.767	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.129.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Totalhight

Tukey HSD[a,b]

Variety	N	Subset for alpha = 0.05	
		1	2
Medjool	30	5.0423	
Berhi	36	5.1703	
Degla- Nour	26		5.5946
Sig.		.720	1.000

Appendix 4.4 Regression Test

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Trunkbiomass, Crownbiomass[b]	.	Enter

a. Dependent Variable: Abovegroundbiomass

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	1.000	.00302

a. Predictors: (Constant), Trunkbiomass, Crownbiomass

a. Dependent Variable: Abovegroundbiomass

b. Predictors: (Constant), Trunkbiomass, Crownbiomass

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.002	.008		.297	.768
	Crownbiomass	1.000	.000	.316	28402.001	.000
	Trunkbiomass	1.000	.000	.975	87761.694	.000

a. Dependent Variable: Abovegroundbiomass

* Curve Estimation.

Curve Fit

Abovegroundbiomass

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.949	.901	.898	14.734

The independent variable is Trunkbiomass.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	67224.021	1	67224.021	309.676	.000
Residual	7380.665	34	217.078		

Total	74604.686	35			

The independent variable is Trunkbiomass.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Trunkbiomass	.973	.055	.949	17.598	.000
(Constant)	186.537	18.011		10.357	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.954	.911	.905	14.203

The independent variable is Trunkbiomass.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	67947.749	2	33973.874	168.416	.000
Residual	6656.937	33	201.725		
Total	74604.686	35			

The independent variable is Trunkbiomass.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Trunkbiomass	2.418	.765	2.358	3.163	.003
Trunkbiomass ** 2	-.002-	.001	-1.412-	-1.894-	.067
(Constant)	-36.018-	118.773		-.303-	.764

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.954	.911	.905	14.203

The independent variable is Trunkbiomass.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	67947.749	2	33973.874	168.416	.000
Residual	6656.937	33	201.725		
Total	74604.686	35			

The independent variable is Trunkbiomass.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Trunkbiomass	2.418	.765	2.358	3.163	.003
Trunkbiomass ** 2	-.002-	.001	-1.412-	-1.894-	.067
(Constant)	-36.018-	118.773		-.303-	.764

Excluded Terms

	Beta In	t	Sig.	Partial Correlation	Minimum Tolerance
Trunkbiomass ** 3[a]	16.817	1.662	.106	.282	.000

a. The tolerance limit for entering variables is reached.

Compound

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.945	.893	.890	.032

The independent variable is Trunkbiomass.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.286	1	.286	284.229	.000

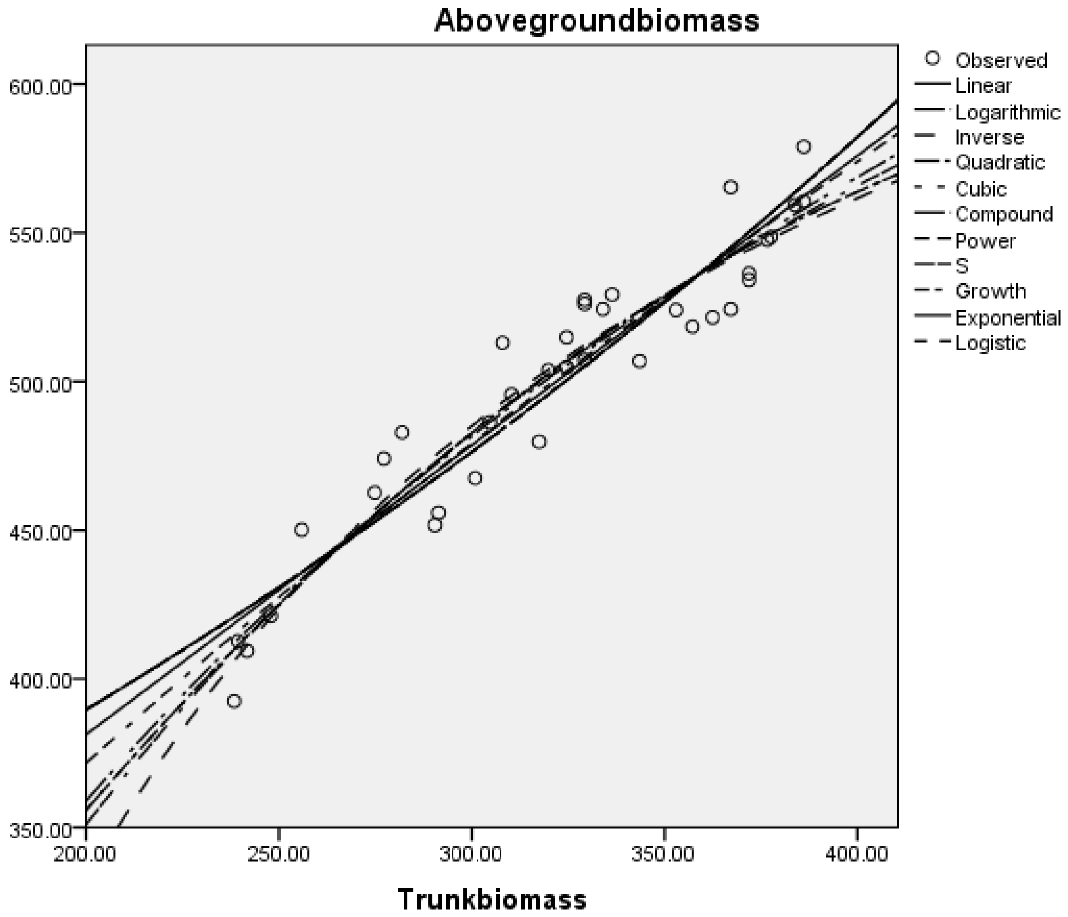
Residual	.034	34	.001		
Total	.321	35			

The independent variable is Trunkbiomass.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Trunkbiomass	1.002	.000	2.573	8392.919	.000
(Constant)	260.697	10.114		25.775	.000

The dependent variable is ln(Abovegroundbiomass).



Nonlinear Regression Analysis

Iteration History[b]

Iteration Number[a]	Residual Sum of Squares	Parameter		
		b0	b1	b2
1.0	18560.562	-35.000-	2.000	-.001-
1.1	6656.937	-36.018-	2.418	-.002-
2.0	6656.937	-36.018-	2.418	-.002-
2.1	6656.937	-36.018-	2.418	-.002-

Derivatives are calculated numerically.[b]

a. Major iteration number is displayed to the left of the decimal, and minor iteration number is to the right of the decimal.

b. Run stopped after 4 model evaluations and 2 derivative evaluations because the relative reduction between successive residual sums of squares is at most SSCON = 1.00E-008.

Parameter Estimates

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
b0	-36.018-	118.773	-277.664-	205.629
b1	2.418	.765	.863	3.973
b2	-.002-	.001	-.005-	.000

Correlations of Parameter Estimates

	b0	b1	b2
b0	1.000	-.997-	.989
b1	-.997-	1.000	-.998-
b2	.989	-.998-	1.000

ANOVA[a]

Source	Sum of Squares	Df	Mean Squares
Regression	9087097.925	3	3029032.642
Residual	6656.937	33	201.725
Uncorrected Total	9093754.862	36	

Corrected Total	74604.686	35	

Dependent variable: Abovegroundbiomass[a]

a. R squared = 1 - (Residual Sum of Squares) / (Corrected Sum of Squares) = .911.

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Trunkbiomass	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Crownbiomass	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: Abovegroundbiomass

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.949[a]	.901	.898	14.73358
2	1.000[b]	1.000	1.000	.00302

a. Predictors: (Constant), Trunkbiomass

b. Predictors: (Constant), Trunkbiomass, Crownbiomass

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	186.537	18.011		10.357	.000
	Trunkbiomass	.973	.055	.949	17.598	.000
2	(Constant)	.002	.008		.297	.768
	Trunkbiomass	1.000	.000	.975	87761.694	.000
	Crownbiomass	1.000	.000	.316	28402.001	.000

a. Dependent Variable: Abovegroundbiomass

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Crownbiomass	.316[b]	28402.001	.000	1.000	.993

a. Dependent Variable: Abovegroundbiomass

b. Predictors in the Model: (Constant), Trunkbiomass

* Curve Estimation.

Curve Fit

Trunkbiomass

Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
1.000	1.000	1.000	.000

The independent variable is Heighttrunk.

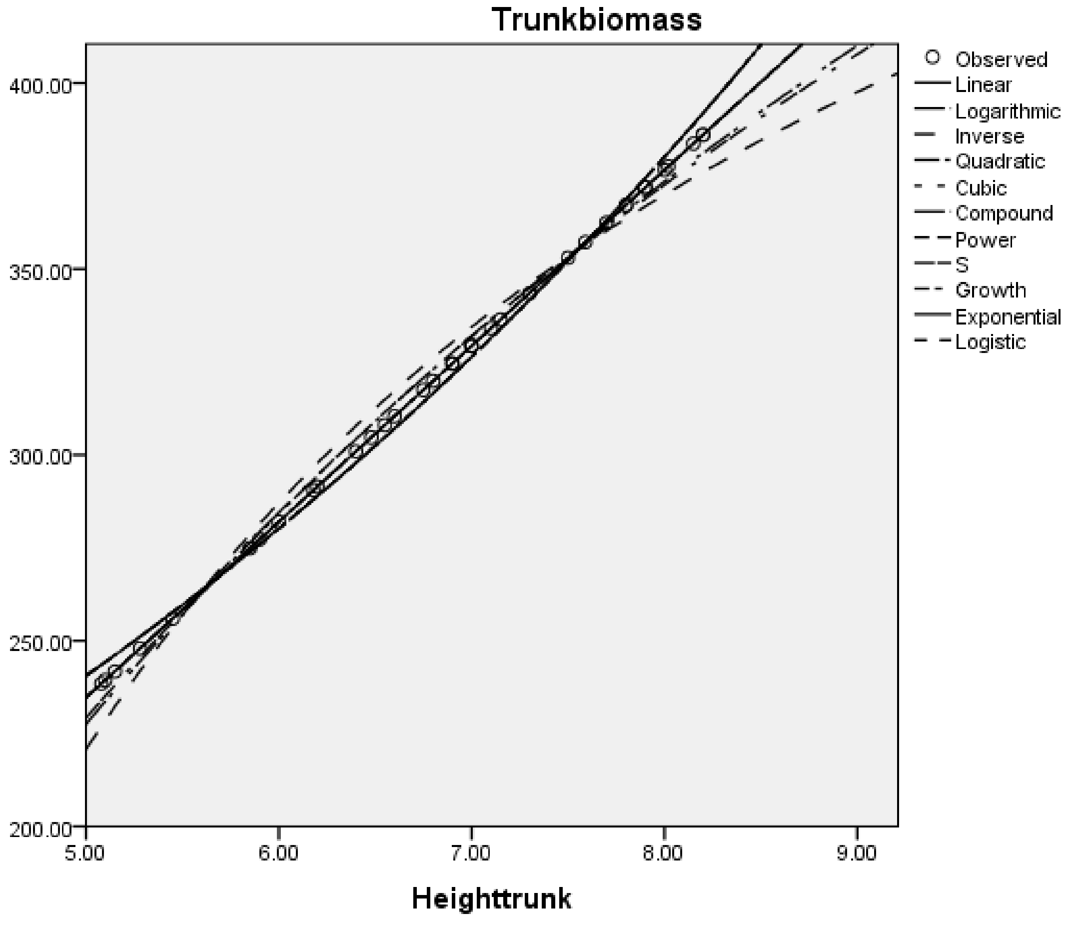
ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	70949.615	1	70949.615	.	.
Residual	.000	34	.000		
Total	70949.615	35			

The independent variable is Heighttrunk.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Heighttrunk	47.335	.000	1.000	.	.
(Constant)	-2.034-	.000		.	.



Variety	Code	Age	Crwon dimetre	Crown length	CA	Ht	Total height	DBH	No. fruits	No. fronds	Crownbiomass	Trunk biomass	AGB	BGB2	Total

Appendix 4.5 : Data collected

Variety	Code	Age	Crown diameter	Crown depth	CA	Ht	Total Height	DBH	No.fronds	No.clusters	Crown biomass	Trunk biomass	AGB	BGB	Total biomass
Medjool	A1	7	6	3	28.26	2.2	5.2	58.28	9	39	67.22651737	102.1028	169.3293174	83.99	253.32
Medjool	A2	7	5.2	2.9	21.2264	1	3.9	50.95	0	32	45.52047474	45.3008	90.82127474	45.0473523	135.87
Medjool	A3	7	4	2.2	12.56	0.6	2.8	25.48			28.15550445		28.15550445	5.23692383	33.39
Medjool	A4	7	4.5	2.7	15.89625	1.5	4.2	38.21	11	27	33.87532645	68.9683	102.8436265	51.0104387	153.85
Medjool	A5	7	4.8	2.58	18.0864	0.95	3.5	36.62			38.24822827		38.24822827	7.11417046	45.36
Medjool	A6	7	4.23	2.72	14.04593	0.9	3.63	35.35			30.57292384		30.57292384	5.68656383	36.26
Medjool	B1	7	6.7	3.05	35.23865	2.3	5.35	54.77	12	45	98.98092855	106.8363	205.8172286	102.085345	307.9
Medjool	B2	7	6.05	3.2	28.73296	2.25	5.45	46.17	10	36	69.01240776	104.46955	173.4819578	86.047051	259.53
Medjool	B3	7	6	2.8	28.26	1.5	4.3	35.66	5	30	67.22651737	68.9683	136.1948174	67.5526294	203.75
Medjool	B4	7	5.5	3.1	23.74625	1.7	4.8	38.21	8	42	52.34463063	78.4353	130.7799306	64.8668456	195.65
Medjool	B5	7	5.3	3	22.05065	1.3	6.6	54.14	3	31	47.64864896	59.5013	107.149949	53.1463747	160.3
Medjool	B6	7	5.5	2.6	23.74625	1.8	4.4	35.03	2	35	52.34463063	83.1688	135.5134306	67.2146616	202.73
Medjool	C1	7	6.5	3.5	33.16625	2.65	6.15	58.91	6	30	88.23858193	123.40355	211.6421319	104.974497	316.62
Medjool	C2	7	5.6	3.5	24.6176	1.5	5	42.99	10	34	54.93509498	68.9683	123.903395	61.4560839	185.36
Medjool	C3	7	5.85	3.1	26.86466	2.4	5.5	57.96	2	27	62.22256082	111.5698	173.7923608	86.201011	259.99
Medjool	C4	7	5.4	3.2	22.8906	1.4	4.6	41.4	7	30	49.91974712	64.2348	114.1545471	56.6206554	170.78
Medjool	C5	7	5	2.9	19.625	1.6	4.5	47.13	9	27	41.65365332	73.7018	115.3554533	57.2163048	172.57

Medjool	C6	7	5.3	3.15	22.05065	1.8	4.95	58.91	10	32	47.64864896	83.1688	130.817449	64.8854547	195.7
Medjool	D1	7	6.5	3.3	33.16625	2.3	5.6	57.32	6	30	88.23858193	106.8363	195.0748819	96.7571414	291.83
Medjool	D2	7	3.4	2.23	9.0746	0.57	2.8	19.75			23.20878215		23.20878215	4.31683348	27.53
Medjool	D3	7	5.7	3.15	25.50465	2.2	5.35	55.73	6	26	57.70395722	102.1028	159.8067572	79.2641516	239.07
Medjool	D4	7	5.1	2.25	28.26	1.7	3.95	46.17	8	34	67.22651737	78.4353	145.6618174	72.2482614	217.91
Medjool	D5	7	4.97	2.78	19.39021	1.17	2.8	54.14			41.11501448		41.11501448	7.64739269	48.76
Medjool	D6	7	5.8	3.05	26.4074	1.8	4.85	47.77	14	40	60.66515227	83.1688	143.8339523	71.3416403	215.18
Medjool	E1	7	3.1	3.3	7.54385	2.15	5.45	54.14	12	25	21.32060701	99.73605	121.056657	60.0441019	181.1
Medjool	E2	7	4.04	2.28	12.81246	1.15	3.78	47.77	10	26	28.55230589	52.40105	80.95335589	40.1528645	121.11
Medjool	E3	7	6.6	2.3	34.1946	2.5	4.8	60.5	10	27	93.41487418	116.3033	209.7181742	104.020214	313.74
Medjool	E4	7	5.1	3	20.41785	1.5	4.5	36.62	7	28	43.52521768	68.9683	112.4935177	55.7967848	168.29
Medjool	E5	7	5.8	3.5	26.4074	2.3	5.8	54.14	6	29	60.66515227	106.8363	167.5014523	83.0807203	250.58
Medjool	E6	7	2.45	2.15	4.711963	0.7	2.85	29.94			18.22308536		18.22308536	6.03184126	24.25
Medjool	F1	7	6.1	3.4	29.20985	2.35	5.75	65.28	10	31	70.86115718	109.20305	180.0642072	89.3118468	269.38
Medjool	F2	7	5.5	3.6	23.74625	2.05	5.65	56.05	5	32	52.34463063	95.00255	147.3471806	73.0842016	220.43
Medjool	F3	7	5.64	2.8	24.97054	1.95	4.75	57.96	9	33	56.02047791	90.26905	146.2895279	72.5596058	218.85
Medjool	F4	7	5.7	2.95	25.50465	2.25	5.2	52.86	13	32	57.70395722	104.46955	162.1735072	80.4380596	242.61
Medjool	F5	7	6.5	3	33.16625	2.3	5.3	50.95	9	35	88.23858193	106.8363	195.0748819	96.7571414	291.83

Medjool	F6	7	6.4	2.94	32.1536	2.7	5.64	51.95	0	36	83.42169006	125.7703	209.1919901	103.759227	312.95
Mean									7.633333	32.03333			129.9267297		
Brhi	A1	7	7.1	2.9	39.57185	1.68	4.58	66.87	12	24	125.855807	77.4886	203.344407	100.858826	304.2
Brhi	A2	7	7.35	3.5	42.40766	2.1	5.6	69.1	14	38	147.2805538	97.3693	244.6498538	121.346328	366
Brhi	A3	7	6.95	3.25	37.91746	2.2	5.45	67.19	7	43	114.8269688	102.1028	216.9297688	107.5971165	324.53
Brhi	A4	7	6.3	2.8	31.15665	1.8	4.6	38.21	8	34	78.93641991	83.1688	162.1052199	80.4041891	242.51
Brhi	A5	7	5.8	2.6	26.4074	1.5	4.1	28.66	6	22	60.66515227	68.9683	129.6334523	64.2981923	193.93
Brhi	A6	7	4.03	2.1	12.74	0.8	2.9	38.21	3	14	28.43785336	35.8338	64.27165336	31.8787401	96.15
Brhi	B1	7	6.8	3.5	36.2984	1.9	5.4	55.09	9	35	104.9699503	87.9023	192.8722503	95.6646361	288.54
Brhi	B2	7	6.72	3.5	35.44934	2.25	5.75	64.33	12	29	100.1437797	104.46955	204.6133297	101.488212	306.1
Brhi	B3	7	6.7	3.3	35.23865	1.9	5.2	57.32	9	36	98.98092855	87.9023	186.8832286	92.6940814	279.58
Brhi	B4	7	6.8	3.49	36.2984	2.5	5.99	0.63	8	30	104.9699503	116.3033	221.2732503	109.7515332	331.02
Brhi	B5	7	6.75	3.51	35.76656	2.25	5.76	61.78	7	33	101.9203744	104.46955	206.3899244	102.3694033	308.76
Brhi	B6	7	6.8	3.5	36.2984	2.3	5.8	62.42	13	30	104.9699503	106.8363	211.8062503	105.0559	316.86
Brhi	C1	7	7.2	3	40.6944	2.1	5.1	57.32	4	28	133.9364043	97.3693	231.3057043	114.7276229	346.03
Brhi	C2	7	7.1	3.06	39.57185	2.15	5.21	58.91	8	32	125.855807	99.73605	225.591857	111.8935361	337.49
Brhi	C3	7	7.15	2.95	40.13116	2.1	5.05	58.59	8	30	129.8191317	97.3693	227.1884317	112.6854622	339.87
Brhi	C4	7	7	3.8	38.465	2.5	6.3	73.88	11	34	118.3656968	116.3033	234.6899668	116.3958222	351.06

Brhi	C5	7	6.05	3	28.73296	1.7	4.7	33.12	6	22	69.01240776	78.4353	147.4477078	73.134063	220.58
Brhi	C6	7	6.7	3.3	35.23865	1.9	5.2	60.19	8	26	98.98092855	87.9023	186.8832286	92.6940814	279.58
Brhi	D1	7	7.15	2.98	40.13116	1.91	4.89	59.55	13	27	129.8191317	88.37565	218.1947817	108.224612	326.42
Brhi	D2	7	7.3	3.25	41.83265	1.9	5.15	68.15	12	30	142.6599245	87.9023	230.5622245	114.358863	344.92
Brhi	D3	7	7.1	3.5	39.57185	2.8	6.3	74.84	13	31	125.855807	130.5038	256.359607	127.154365	383.51
Brhi	D4	7	7.5	3.32	44.15625	2.4	5.72	66.87	9	30	162.2716419	111.5698	273.8414419	135.825355	409.67
Brhi	D5	7	7.4	3.3	42.9866	2.25	5.55	64.96	8	31	152.0839282	104.46955	256.5534782	127.250525	383.8
Brhi	D6	7	5.81	2.6	26.49854	1.52	4.12	28.98	9	25	60.97242249	69.915	130.8874225	64.9201616	195.81
Brhi	E1	7	7.1	2.9	39.57185	2	4.9	58.28	12	33	125.855807	92.6358	218.491607	108.371837	326.86
Brhi	E2	7	8	2.8	50.24	2.06	4.86	76.43	13	37	227.3572641	95.4759	322.8331641	160.125249	482.96
Brhi	E3	7	7.35	3.23	42.40766	1.9	5.13	67.83	11	31	147.2805538	87.9023	235.1828538	116.650696	351.83
Brhi	E4	7	7.4	3.25	42.9866	2.1	5.35	79.61	12	35	152.0839282	97.3693	249.4532282	123.728801	373.18
Brhi	E5	7	6.5	3	33.16625	1.5	4.5	35.03	6	23	88.23858193	68.9683	157.2068819	77.9746134	235.18
Brhi	E6	7	7.5	3.28	44.15625	2.15	5.43	54.14	13	29	162.2716419	99.73605	262.0076919	129.955815	391.96
Brhi	F1	7	7.15	2.97	40.13116	1.91	4.88	56.68	9	31	129.8191317	88.37565	218.1947817	108.224612	326.42
Brhi	F2	7	7.1	2.85	39.57185	2.1	4.95	57.32	11	30	125.855807	97.3693	223.225107	110.719653	333.94
Brhi	F3	7	7.95	3.95	49.61396	2.06	6.01	0.63	10	30	219.6023532	95.4759	315.0782532	156.278814	471.36
Brhi	F4	7	6.32	3.15	31.35478	1.95	5.1	57.32	16	29	79.80819691	90.26905	170.0772469	84.3583145	254.44

Brhi	F5	7	6.3	3.2	31.15665	2	5.2	50.95	15	32	78.93641991	92.6358	171.5722199	85.0998211	256.67
Brhi	F6	7	7.38	3.3	42.75455	2.1	5.4	66.87	14	35	150.1401402	97.3693	247.5094402	122.764682	370.27
Mean									9.972222	30.25			212.6413874		
Deg-Nour	A1	7	7.45	3.6	43.56946	2.55	6.15	61.46	14	50	157.0781323	118.67005	275.7481823	136.771098	412.52
Deg-Nour	A2	7	7.6	3	45.3416	2.6	5.6	55.73	15	42	173.2925597	121.0368	294.3293597	145.987362	440.32
Deg-Nour	A3	7	7.1	3.25	39.57185	2	5.25	51.91	11	40	125.855807	92.6358	218.491607	108.371837	326.86
Deg-Nour	A4	7													
Deg-Nour	A5	7	7.2	3.2	40.6944	2.1	5.3	54.14	16	40	133.9364043	97.3693	231.3057043	114.727629	346.03
Deg-Nour	A6	7	7.4	3.15	42.9866	2.6	5.75	58.28	13	36	152.0839282	121.0368	273.1207282	135.467881	408.59
Deg-Nour	B1	7	7.1	2.95	39.57185	2	4.95	58.91	12	30	125.855807	92.6358	218.491607	108.371837	326.86
Deg-Nour	B2	7	7.07	3.1	39.23815	2.2	5.3	57.32	17	25	123.5490332	102.1028	225.6518332	111.923309	337.58
Deg-Nour	B3	7	7.15	3	40.13116	2.75	5.75	0.63	17	35	129.8191317	128.13705	257.9561817	127.946266	385.9
Deg-Nour	B4	7	7.5	2.9	44.15625	2.85	5.75	62.1	14	45	162.2716419	132.87055	295.1421919	146.390527	441.53
Deg-Nour	B5	7	6.2	2.5	30.1754	1.75	4.25	46.17	11	30	74.75734072	80.80205	155.5593907	77.1574578	232.72
Deg-Nour	B6	7	7.35	3.3	42.40766	2.65	5.95	58.91	17	35	147.2805538	123.40355	270.6841038	134.259316	404.94
Deg-Nour	C1	7	6.3	3.1	31.15665	1.8	4.9	50.95	9	35	78.93641991	83.1688	162.1052199	80.4041891	242.51
Deg-Nour	C2	7	7.4	3.3	42.9866	2.65	5.95	0.63	18	45	152.0839282	123.40355	275.4874782	136.641789	412.13
Deg-Nour	C3	7	7.7	3.55	46.54265	2.8	6.35	61.78	17	42	185.2231135	130.5038	315.7269135	156.600549	472.33
Deg-Nour	C4	7	7.6	3.5	45.3416	2.9	6.4	60.5	14	41	173.2925597	135.2373	308.529859	153.03081	461.56

													7		
Deg-Nour	C5	7	7.73	3.47	46.90603	2.7	6.17	62.1	21	41	188.9920191	125.7703	314.7623191	156.12211	470.88
Deg-Nour	C6	7	7.5	2.9	44.15625	2.3	5.2	57.32	18	39	162.2716419	106.8363	269.1079419	133.477539	402.59
Deg-Nour	D1	7													
Deg-Nour	D2	7	7.2	3.3	40.6944	2	5.3	57.32	15	40	133.9364043	92.6358	226.5722043	112.379813	338.95
Deg-Nour	D3	7	7.5	3.4	44.15625	2.9	6.3	65.28	20	30	162.2716419	96.5644	258.8360419	128.382677	387.22
Deg-Nour	D4	7											0		
Deg-Nour	D5	7	7.45	3.8	43.56946	2.33	6.13	58.28	19	34	157.0781323	108.25635	265.3344823	131.605903	396.94
Deg-Nour	D6	7	7.3	3.1	41.83265	2.2	5.3	55.73	13	26	142.6599245	102.1028	244.7627245	121.402311	366.17
Deg-Nour	E1	7													
Deg-Nour	E2	7	6.3	3.2	31.15665	1.9	5.1	51.91	12	34	78.93641991	87.9023	166.8387199	82.7520051	249.59
Deg-Nour	E3	7	7.5	3.35	44.15625	2.85	6.2	0.63	18	48	162.2716419	132.87055	295.1421919	146.390527	441.53
Deg-Nour	E4	7	7.15	3.8	40.13116	2.4	6.2	54.14	15	35	129.8191317	111.5698	241.3889317	119.72891	361.12
Deg-Nour	E5	7	7.37	2.9	42.63877	1.91	4.81	52.54	12	40	149.17953	88.37565	237.55518	117.827369	355.38
Deg-Nour	E6	7	7.4	2.85	42.9866	2.3	5.15	57.96	16	36	152.0839282	106.8363	258.9202282	128.424433	387.34
									15.15385	37.46154			242.8722714		
Deg-Nour	F1	7													
Deg-Nour	F2	7													
Deg-Nour	F3	7													
Deg-Nour	F4	7													
Deg-Nour	F5	7													

Deg-Nour	F6	7													
						Trunk height									
Medjool	J1	12	7.42	3.2	43.21927	5.08	8.28	50.95	11	47	154.0582447	238.4276	392.49	97.34	489.83
Medjool	J2	12	7.55	3.05	44.74696	5.15	8.2	50.31	12	50	167.6733442	241.74105	409.41	101.53	510.94
Medjool	J3	12	7.5	3.2	44.15625	6.75	9.95	57.96	16	60	162.2716419	317.47705	479.75	118.98	598.73
Medjool	J4	12	7.45	2.98	43.56946	7.8	10.78	55.73	14	55	157.0781323	367.1788	524.26	130.02	654.28
Medjool	J5	12	7.52	3	44.39206	6.2	9.2	65.92	15	58	164.4068277	291.4428	455.85	113.05	568.9
Medjool	J6	12	7.49	3.1	44.03858	7.59	10.69	54.14	13	52	161.2165751	357.23845	518.46	128.58	647.04
Medjool	I7	12	7.74	2.93	47.02747	6.9	9.83	53.8	10	65	190.2685985	324.5773	514.85	127.68	642.53
Medjool	I8	12	7.85	3.07	48.37366	6.55	9.62	54.77	14	60	205.0108201	308.01005	513.02	127.23	640.25
Medjool	I9	12	7.6	3.2	45.3416	5.28	8.48	54.14	15	54	173.2925597	247.8946	421.19	104.46	525.65
Medjool	I10	12	7.7	3.03	46.54265	6.6	9.63	47.45	20	45	185.2231135	310.3768	495.6	122.91	618.51
Medjool	I11	12	7.79	3.3	47.63702	5.9	9.2	47.45	16	65	196.8077009	277.2423	474.05	117.56	591.61
Medjool	I12	12	7.64	2.95	45.82014	7	9.95	55.41	13	69	177.951095	329.3108	507.26	125.8	633.06
Medjool	K13	12	7.5	3.06	44.15625	7.9	10.96	56.68	15	74	162.2716419	371.9123	534.18	132.48	666.66
Medjool	K14	12	7.58	3	45.10327	8	11	56.05	10	67	171.0181568	376.6458	547.66	135.82	683.48
Medjool	K15	12	7.6	3.32	45.3416	5.1	8.42	50.95	5	64	173.2925597	239.3743	412.67	102.34	515.01
Medjool	K16	12	7.62	3.1	45.58055	8.15	11.25	59.55	13	70	175.6033235	383.74605	559.35	138.72	698.07
Medjool	K17	12	7.8	3.2	47.7594	7.8	11	55.73	14	50	198.1474196	367.1788	565.33	140.2	705.53
Medjool	K18	12	7.47	3.05	43.80371	7.7	10.75	60.5	13	56	159.1311313	362.4453	521.58	129.35	650.93
Medjool	L19	12	7.58	3.1	45.10327	8.02	11.12	55.09	16	65	171.0181568	377.5925	548.61	136.06	684.67
Medjool	LI20	12	7.52	3.06	44.39206	7.9	10.96	52.54	15	65	164.4068277	371.9123	536.32	133.01	669.33
Medjool	L21	12	7.61	3	45.461	8.2	11.2	50	14	60	174.4433564	386.1128	560.56	139.02	699.58
Medjool	L22	12	7.8	3.1	47.7594	7	10.1	51.59	7	55	198.1474196	329.3108	527.46	130.81	658.27

Medjool	L23	12	7.76	3.3	47.27082	8.2	11.5	55.73	15	68	192.8527195	386.1128	578.97	143.58	722.55
Medjool	L24	12	7.61	2.95	47.27082	7.15	10.1	55.41	13	70	192.8527195	336.41105	529.26	131.26	660.52
Medjool	M25	12	7.58	3.03	45.10327	7.5	10.53	56.68	14	75	171.0181568	352.9783	524	129.95	653.95
Medjool	M26	12	7.67	3.2	46.18069	6.48	9.68	54.14	8	60	181.5435876	304.6966	486.24	120.59	606.83
Medjool	M27	12	7.66	3.06	46.06035	6.9	9.96	53.18	11	67	180.3365336	324.5773	504.91	125.22	630.13
Medjool	M28	12	7.72	3.35	46.78474	5.85	9.2	55.09	5	48	187.7256385	274.87555	462.6	114.72	577.32
Medjool	M29	12	7.54	3.05	44.62851	6.4	9.45	48.72	6	60	166.5759074	300.9098	467.49	115.94	583.43
Medjool	M30	12	7.77	2.95	47.39273	5.45	8.4	49.36	9	40	194.1604461	255.94155	450.1	111.62	561.72
Medjool	N31	12	7.49	3	44.03858	6.18	9.18	48.72	16	52	161.2165751	290.4961	451.71	112.02	563.73
Medjool	N32	12	7.69	3.1	46.42184	6.8	9.9	50	8	35	183.9867911	319.8438	503.83	124.95	628.78
Medjool	N33	12	7.74	2.9	47.02747	7.1	10	50.95	13	45	190.2685985	334.0443	524.31	130.03	654.34
Medjool	N34	12	7.79	3.15	47.63702	7	10.15	56.36	8	60	196.8077009	329.3108	526.12	130.48	656.6
Medjool	N35	12	7.51	3.2	44.27408	7.3	10.5	57.32	9	63	163.3350351	343.5113	506.85	125.7	632.55
Medjool	N36	12	7.82	3.05	48.00463	6	9.05	56.05	13	50	200.8595227	281.9758	482.84	119.74	602.58