ПРОБЛЕМЫ ЭКОЛОГИИ И РАЦИОНАЛЬНОГО ПРИРОДОПОЛЬЗОВАНИЯ. БИОТЕХНОЛОГИИ
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Estimation of Cilicican fir dendrometry variables in the Fir and Cedar Reserve of Syria

B. Tobo✉, W. Ali, R. Karmoka, A. Mahmoud
Agricultural Research Center,
215, Buga St., Tishreen suburb, Latakia, 424079, Syria
bashar.tobo@Tishreen.edu.sy✉

Introduction. *The Mediterranean forests provide wide range of social and economic benefits for the local communities. This is especially true for Syrian forests, which are under influence of the crisis that the country suffered from. In this respect, there is need in more precise technologies for forest inventory and monitoring for sustainable forest management.* ***The aim of the research*** *is to determine the woody production and growth characteristics of Cilicican fir (Abies cilicica) trees that are found in the Lattakia Governorate's Fir and Cedars Reserve of Syria.* ***The object of research.*** *Shuh forest is located in the northern part of the Syrian coastal mountain range, on the western slope of the summit of Jabal Al-Nabi Matta.* ***Research methods.*** *Within the research, remote sensing technology and Sentinel image processing were employed to estimate some forest growth factors, where maps were produced expressing growth factors through multiple regression analyses between sample location variables and corresponding pixel values for all ratios and indicators used.* ***Results and conclusions.*** *All the studied variables showed a significant correlation R that exceeded 0.75 with the wood stock, while the response to the density was lower as it did not exceed the value of 0.33 despite it being significant. The maps of the* variables *were produced using the* derived *regression equation for each indicator. The highest accuracy for the wood stock was 77 and 72 % for the average height. As for the estimated accuracy of the model, the average value of the deviation of the values of the* variables *estimated by the formula from the field measured was 6.08; 9.1; 9.6 and 8–12 % for models estimating the average height, average diameter, wood stock, and base area, respectively.*

Keywords: *Abies Cilicica; Fir and Cedar reserve; wood productivity; mean annual increment; exposure; Syria; growth factors; Sentinel*

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Introduction. The Mediterranean biome covers about 20 % of the Earth's surface. Of the five Mediterranean climate zones worldwide, the Mediterranean Basin constitutes the largest domain with about 25,000 plant species, more than half of which are endemic [1]. The forest wealth in Syria constitutes a unique natural heritage in terms of biodiversity and genetic diversity [2]. The area of forests in Syria is 527,494 ha, equivalent to (2.5 %) of the country's area, of which natural forests constitute 232,840 ha, while industrial forests occupy an area of 294,654 ha [3]. The Mediterranean forests play an important social and economic role by providing wood and non-wood forest products [4].

Sustainably produced wood and paper goods are a wise, renewable, and environmentally friendly choice compared to other materials such as plastic, which alone uses 4 % of the world's total oil production. Similarly, energy production from wood and forest-based biomass can displace other greenhouse gas-emitting products, such as oil and coal [5]. The study of forest growth is necessary to determine the breeding methods necessary to achieve the quantitative and qualitative specifications required for the produced wood, the cutting cycle system and the quantities of wood to be invested [6]. And to secure wood production in the best possible conditions while preserving the fertility of the site and the balance of forest groups. It expresses the productivity of a site, which is defined as the volume of wood produced by a certain forest group at a certain age taken as a reference or the average annual growth of this group at this age [7] about the fertility of this site and related to the common action of several factors interacting with each other, which can be divided into two main groups: the first group is related to the forest site itself and its degree of fertility, while the second group is related to the composition and structure of the forest group and the breeding processes applied in it, in addition to the human activity that may affect forest productivity positively or negatively. Accordingly, the productivity of a site results from the interaction of these factors combined, as one factor alone cannot give an accurate idea of this productivity. The dynamic nature of forest productivity, which makes it variable according to many factors, requires the forester to consider this in the organization and management plans and through the comprehensive review and evaluation of these plans while trying to maintain and increase this productivity over time [8].

Sustainable development and rational use of forest resources are the basis for integrated management of forest resources, which relies on correct information periodically and within limited time periods about their spatial distribution and growth parameters such as phytomass, density, and woody stock, which is difficult to achieve periodically through traditional methods, which makes use of remote sensing technologies. Satellite data and geographic information systems (GIS) are the best method with their reasonable cost and acceptable accuracy of results, in addition to the high temporal recurrence of their data, the comprehensive vision they provide, and the effort that can be made to estimate the growth coefficients of the site [9, 10]. Many studies have also been conducted to estimate the density and coverage of forests in national parks and areas covered by extensive forests [11, 12].

The importance of the research

In light of the great changes that occurred in the Syrian forests and structure under the influence of the crisis that the country suffered from, it is necessary to go back again to enumerate the forest areas in Syria, especially in Lattakia governorate, which is considered one of the richest Syrian governorates in forest wealth. There is need in additional study of the current reality of the most important forest species, especially those threatened with extinction, including the pure Cilicican fir (*Abies cilicica*) communities in the Fir and Cedars Reserve in Slunfah. This research is also important in terms of establishment of the forestry database (diameters at breast height and wood stock) using traditional inventory processes in conjunction with the capabilities of analyzing Sentinel satellite images at the pixel level. The research results can help those in charge of the forestry process to develop a preconception of integrated management plan for these forest groups and management process of the Syrian forests.

Purpose and objectives of the work

The aim of this research is to estimate the growth and wood yield of Cilician fir trees located in the Fir and Cedar Reserve in Lattakia Governorate and to establish a database of dendrometry indexes (diameters, heights, and wood stocks) using traditional inventories. Achieving this goal required solving the following tasks:

- Carry out field research with the establishment of test plots in forest stands in the study area in 2020.
- Analyse and process the satellite image Sentinel-2B.
- Produce maps expressing growth variables through multiple regression.

Assess the accuracy of the resulting thematic maps.

Study area

Shuh (fir) forest is located in the northern part of the Syrian coastal mountain range, on the western slope of the summit of Al-Nabi Matta, at altitudes ranging from 1200–1570 m above sea level, between Bab Jannah, the village of Al-Shouh, and the TV station in Lattakia Governorate, with an area of 978 ha [13] (Fig. 1). The forest lands are characterized by steep slopes ranging from 20 to 27 degrees. It is dotted with cracked calcareous and dolomitic rocks from the Cretaceous era, covered with Mediterranean red soil. Under the conditions of forest vegetation, climatic factors and topography, they developed into forest soils. At higher elevations, soils that are very rich in undecomposed organic matter, called carbonaceous humic soils, develop. At lower elevations, the soil of the Mediterranean brown forest develops [14]. The study area enjoys a Mediterranean climate characterized by rainy winters, in which rain falls in the form of heavy and short-term showers. The summer is hot and dry. The annual average of precipitation is 1,400 mm, with some snowfalls whose annual average exceeds three days and may reach ten days with the increase in altitude. The average minimum temperature during January is 0.76 degrees Celsius, and the average maximum temperature during August is 23.9 degrees Celsius [14].

Materials and Methods

Satellite images and maps. For the research we used a Sentinel 2B image (spatial resolution 10 m) on 05.05.2020 at the time of the field surveys, SRTM data to extract terrain Data (elevation, Slope, and aspect), and topographical maps of 1:50000 scales to infer urban areas and Road network. The processing and output of satellite images were carried out using ERDAS Imagine and Arc GIS software.

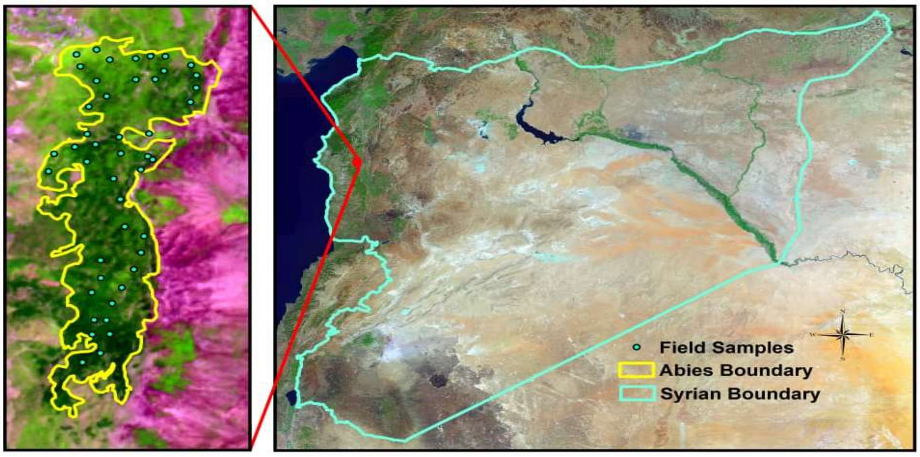


Fig. 1. Map showing the nucleus of the Fir and Cedar reserves in the Syrian coastal mountain range. The points within the nucleus of the reserve indicate the centres of the excised samples in the study area

Рис. 1. Карта, на которой показано ядро заповедника «Пихта и кедр» в Сирийском прибрежном горном массиве. Точками внутри заповедного ядра обозначены центры выделенных участков на исследуемой территории

Sampling. 46 circular samples of an area of 400 m^2 each with a radius of 11.3 m were taken in 2020. The samples were distributed over five different aspects to include most of the discrepancies that exist between aspects in the study area, namely: the western (11 samples), the eastern (8 checks), the northern (6 checks), the northwestern (7 checks), and the southwestern (14 checks). Knowing that the age of the trees in the forest was estimated using the Pressler probe, the average age of the trees was 118 years. The diameters of all the trees in the sample were measured at breast height (1.3 m) using a caliper. A Blume-Leiss dendrometer was used to measure the tree height, a GPS device was used to locate the sample coordinates and take their coordinate points, and spray paint of different colours were used to mark the measured trees and centre of samples.

Estimation of wood growth and productivity. To determine the indicators of growth and productivity of Shuh trees in the studied site, we measured a number of forestry parameters in all the study samples. The total number of trees measured in all samples was 1,239, and the variables measured in the samples included the number of trees in the sample (n), diameter DBH (1.3 m), full height H (m) for all sample trees from ground level to the top of the tree, and the average value of each indicator was calculated at the level of the forest group or site.

All trees in the sample with a diameter exceeding 10 cm at breast height were counted. ***Tree density*** was calculated according to the equation:

$$N = \sum n/A \text{ (tree/ha)}, \qquad (1)$$

where N – number of trees in ha (tree/ha), n – the number of trees in the sample (tree), A – sample area (ha).

The ***basal area*** of each of the sample trees was calculated according to the equation:

$$gi = \pi * dbh^2/4*10000 \text{ (m}^2\text{/ha)}, \qquad (2)$$

where gi – the basal area of the i tree (m^2).

Then, the basal area was calculated at the sample level by dividing it by the sample area (0.04 e) according to the following equation:

$$G = \sum gi/A \text{ (m}^2\text{/ha)}, \qquad (3)$$

where G – the basal area in ha (m^2/ha), gi – the basal area of the i tree (m^2), A – sample area (ha).

The ***wood stock*** Vi (m^3), was calculated for each sample tree according to the basic equation for calculating the standing tree volumes:

$$Vi = gi*hi*fi \text{ (m}^3\text{/ha)}, \qquad (4)$$

where Vi – the woody volume of tree i in m^3, fi – shape modulus of keloid fir trees (f=0.5), hi – the height of tree i in m, gi – the basal area of tree i (m^2).

Then the wood stock was calculated at the sample level according to the following equation:

$$V = \sum Vi/A \text{ (m}^3\text{/ha)}, \qquad (5)$$

where V – wood stock in hectares (m^3/ha).

The following equation was applied to calculate the annual growth rate (m^3/ha/year) for fir trees in the studied site.

$$MAI = V/T \text{ (m}^3\text{/ha/year)}, \qquad (6)$$

where V – wood stock in hectares (m^3/ha), MAI – annual growth rate (m^3/ha/year), T – age (years).

Sensitive study. Principle Component Analysis and images of topographical parameters (Elevation, Sloop, and Aspect) were used in research analyses.

Vegetation indices

Simple Ratio Vegetation Index (SVR):

$$SVR = NIR/R. \qquad (7)$$

The simplest vegetation cover indicator is called the vegetation percentage index. Its value is close to 1 for targets of water and barren land. It increases for vegetation targets until it exceeds the value of 35 with an increase in the density of vegetation cover.

Normalized difference vegetation index (NDVI):

$$NDVI = (NIR - R)/(NIR + R). \qquad (8)$$

The numeric values of NDVI image pixels range from +1 to -1 and the bit values are always in the positive range [15].

Enhanced vegetation index (EVI)

It includes the blue spectral range in order to improve the effect of the atmosphere and the effect of the canopy, and it interacts well with the physiology of the Vegetation cover and with the structure and composition of the crown [16]:

$$EVI=2.5*(NIR-R)/(NIR+6R-7.5BLUE+1). \quad (9)$$

Soil Adjusted Vegetation Index (SAVI)

It is a modified NDVI vegetative index calibrated on the basis of the effect of soil reflectivity on the transmission of infrared and near-infrared radiation through the crowns of plants [16]:

$$SAVI=(NIR-R)/(NIR+R+L)*(1+L), \quad (10)$$

where L– Adjusted Factor, which is determined within the equation by the value (0.5).

Green Chlorophyll Index (GCI)

Used to estimate the chlorophyll content of plant leaves [17].

$$GCI=(NIR/Green)-1. \quad (11)$$

Principal Component Analysis (PCA) is a standard linear method for dimensionality reduction and feature extraction. Its aim is to convert the large amount of data that has scattered characteristics into data that contains the basic characteristics of the image. The first band contains the largest contrast ratio between information, and the latter contains noise as it contains the lowest contrast ratio [18].

Within the research, the basic component analysis was carried out on two levels:

- Direct image Band PCA six levels.
- Combined spectral indicators, which concentrates the derived data into a limited set of ranges and 6 levels of this derivation.

Using Arc GIS Software, a raster product were prepared that reflects the sites and data of the field surveys. The images Represent vegetation indices were derived, the Principal component analysis were performed, and then the pixel values corresponding to the sites of the field surveys were extracted from all derived indices and recorded and processed via ERDAS Imagine software environment. The SPSS program was used to study the correlation values (Table 1) between the growth coefficient data measured at the sample locations and the corresponding values from the ranges resulting from the derived spectral indices

The multiple linear regression method was used within the SPSS statistical analysis program to build a mathematical model for each of the growth parameters using the values of spectral vegetation indicators and principal components analysis with the values of field surveys for 33 randomly selected sites from the sample sites and left data for 13 sites to test the accuracy of the models. The stepwise regression method was used in the statistical analysis program SPSS to overcome the issue of identifying the most influential factors in the model [19] and to determine the most affecting the most fitting indices.

Table 1. Correlation coefficients between the values of the field surveys and their corresponding pixels from the image products

Таблица 1. Коэффициенты корреляции между значениями, полученными в ходе полевых измерений, и соответствующими им пикселями на продуктах спутниковой съёмки

	Density	Basal area	Wood stock	Average diameters	Average heights
SVI	-0.279	0.632**	0.620**	0.632**	0.718**
PCA4 (image bands)	-0.137	-0.505*	-0.515*	-0.433	-0.380
PCA3 (Indices)	0.174	-0.572*	-0.576*	-0.585**	-0.578**
Elevation	-0.109	-0.532*	-0.518*	-0.489	-0.557*
Aspect	0.301*	0.670**	0.655**	0.659**	0.584**
** Correlation is significant at the 0.01 level					
* Correlation is significant at the 0.05 level					

Results and Discussion

According to distribution of Diameter and heights classes in the studied samples

It could be noted from Fig. 2 that the measured trees were distributed according to their diameters within five classes with a range of 16 cm between them, and the largest number of trees in the studied site belonged to the diameter classes (27.4–43.8–60.2) cm respectively.

It could be also follow up from Fig. 3 that the measured trees were distributed within five classes in terms of height, with a range of (6 m) between one row and the other. Most of the trees belong to the row of height (15–21–33), respectively. While the row of height 39 m accounted for the least number of trees.

Wood stock basic forestry parameters. The parameters (variables or coefficients) show the forestry parameters (variables that can be measured and change with time, such as the DBH and the total height of trees) calculated for Cilician fir trees in the studied samples (Table 2). The highest value of the basal area and the wood stock was in the south-western aspect with a value of 70.4 m^2/ha for the basal area and 883.8 m^3/ha for the wood stock with a tree density of 487 trees/ha, followed by the western aspect with a value of 57.1 m^2/ha for the basal area and 655.8 m^3/ha for the wood stock with a tree density of 518 trees/ha. It was followed by the northwestern aspect with a value of 56.4 m^2/ha for the basal area, a value of 651.4 m^3/ha for wood stock, and a tree density of 529 trees/ha. While the lowest value was recorded for the basal area of 37.2 m^2/ha and the wood stock of 374.8 m^3/ha in the northern aspect with a tree density of 525 trees/ha, followed by the eastern aspect with a value of 34.8 m^2/ha for the area and 358 m^3/ha for the wood stock and a tree density of 514 trees/ha (Table 2).

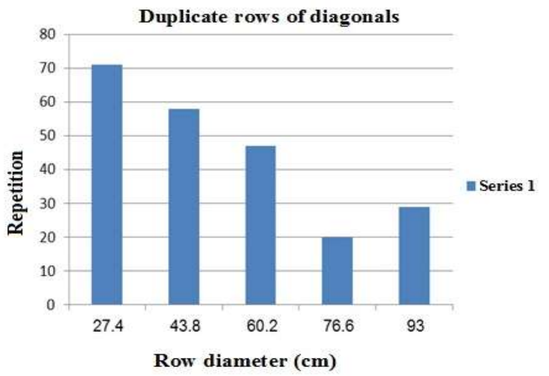


Fig. 2. Distribution of DBH in the studies samples

Рис. 2. Распределение деревьев по диаметру на высоте груди на исследуемых участках

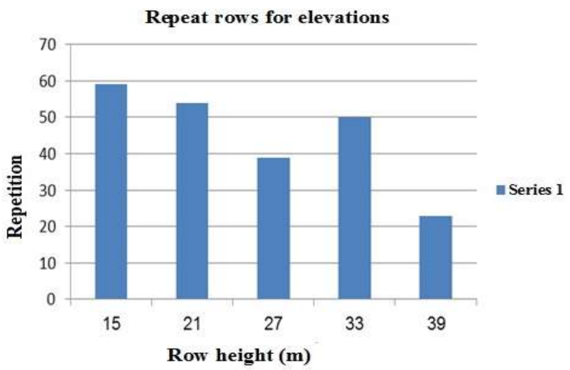


Fig. 3. Distribution of trees heights in the studies samples

Рис. 3. Распределение деревьев по высоте на исследуемых участках

Table 2. Basic forestry parameters calculated for trees of the studied species according to each gallery

Таблица 2. Основные таксационные показатели, рассчитанные для деревьев изучаемых пород по каждой галерее

Exposure	Plot Nr.	G (m^2/ha)	V (m^3/ha)	N (tree/ha)	dbh average (cm)	H average (m)	MAL (m^3/ha/year)
W	11	57.1	655.8	518	36	23	5.5
E	8	34.8	358.0	514	27	18	3.0
N	7	37.2	374.8	525	29	20	3.2
N.W	7	56.4	651.4	529	35	22	5.1
S.W	14	70.4	883.8	487	41	24	7.5

It is also noted from Table 2 that the values of the annual growth rate in each of the southwestern, western, and northwestern exhibitions exceed their counterparts in the eastern and northern exhibitions, where the annual growth rate achieved a value of 7.5 m^3/ha/year in the southwestern exhibition, followed by the western exhibition with a value of 5.5 m^3/ha/year, while the value of the annual growth rate in the northwestern exhibition was 5.1 m^3/ha/year. The lowest value of the annual growth rate in the eastern and northern exhibits was 3.2 m^3/ha/year in the northern exhibit and 3 m^3/ha/year in the eastern exhibit. This is consistent with many studies on this species, including the study conducted by [20] to evaluate the growth of Kilikian fir seedlings planted under Turkey oak trees in the wet and sweet bioclimatic floor in the Syrian coastal mountains. The results of the study showed that the diagonal and longitudinal growth of trees was characterized by a slight increase in the first years of cultivation, which soon accelerated with the ageing of trees, to correspond with the evolutionary characteristics of shade types.

The study indicated that the density of fir was significantly higher than that of Turkey oak per unit area, and the average height of the studied fir trees was 14 m and their diameter at ground level was 4.2 cm. The average age of fir trees in our study was about 118 years. The value of the wood stock and the basal area differed from the values obtained. The study [21], showed that the average age of fir trees ranged between 30 and 40 years, the basal area was 22.08 m^2/ha, and the wood stock was 88 m^3/ha, at an average height of 8 m, and an average diameter of 12 cm. This is due to difference in age and some of the characteristics of the site (soil, density). These values also differed from the values obtained by [22], where the wood stock of the forest group dominated by fir and mentioned by [22] was about 164 m^3/ha (88 m3/ha with an average annual growth between 2.2–2.9 m^3/ha for fir trees and 76 m^3/ha with an average annual growth of 2 m^3/ha for the fir tree) at a density of 955 trees/ha, for the same reasons as above, of different age, density, and some site characteristics.

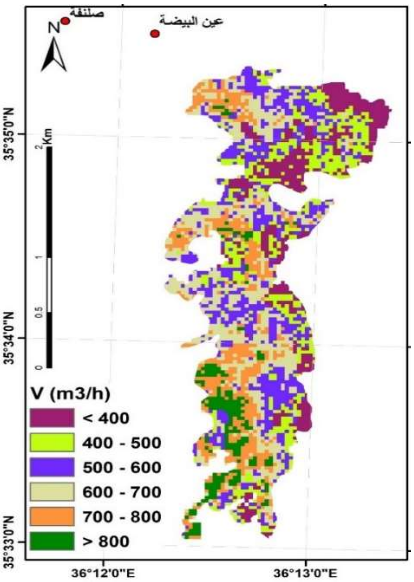
Models for estimating growth coefficients by processing satellite images. The studied growth variables showed good and significant correlation values.

Tree density was only significantly correlated with the slope degree and had the lowest value among all correlation values, 0.339. The regression model that most expresses the changes in the values of the studied coefficients has been extracted According to the most fitting coefficients Table 3. The equations were applied to the Derived, and an accuracy test was implemented within the ERDAS program, and maps expressing the growth variables of the study area were produced (Fig. 4).

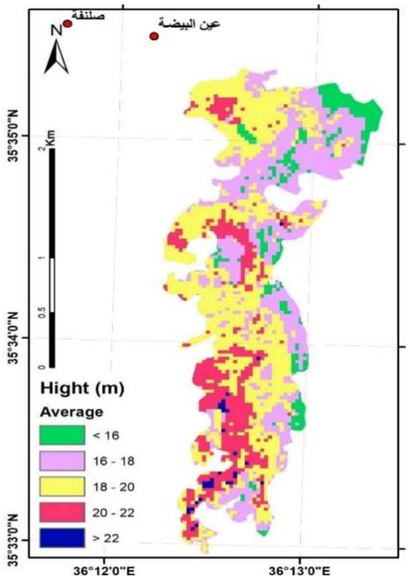
The growth variables were classified into classes, as shown in (Fig. 4), in order to improve their presentation and to enable verification of the suitability of the equation at the class level. The accuracy of the resulting image was estimated through an accuracy assessment within the ERDAS program using the data from 13 field verification sites (Table 4).

Table 3. Multiple regression equations for the studied growth coefficients (higher correlation values)
Таблица 3. Уравнения множественной регрессии для изучаемых коэффициентов роста (более высокие значения корреляции)

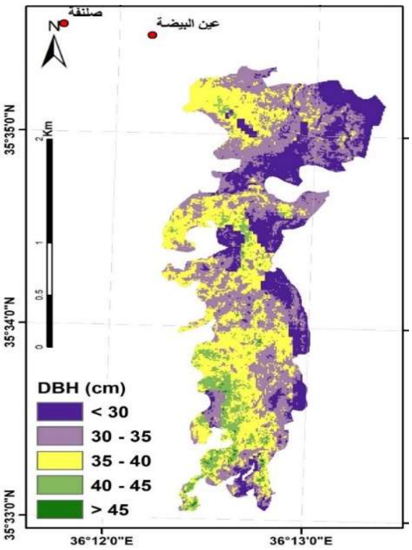
Growth coefficients	Regression equation	R	R2
Average heights	= 32.3 + (2.4 * SVI) – (0.016 * Elevation) – (1.05 * PCA3 _Indices) + + (0.009 * Aspect)	0.74	0.55
Average diameters	= 65.4 + (0.03 * Aspect) – (2.8 * PCA3 _Indices) – (0.03 * Elevation)	0.70	0.49
Basal area	= 152.4 + (0.06 * Aspect) – (7.82 * PCA3 _Indices) – (0.09* Elevation) – – (0.02 * PCA4_image bands)	0.75	0.57
Wooden stock	= 2052 + (0.84* Aspect) – (116.3 * PCA3 _Indices) – (1.28 * Elevation) – – (0.33 * PCA4_image bands)	0.75	0.56
Tree density	= 747.959 + (2.135 * Slope)	0.33	0.11



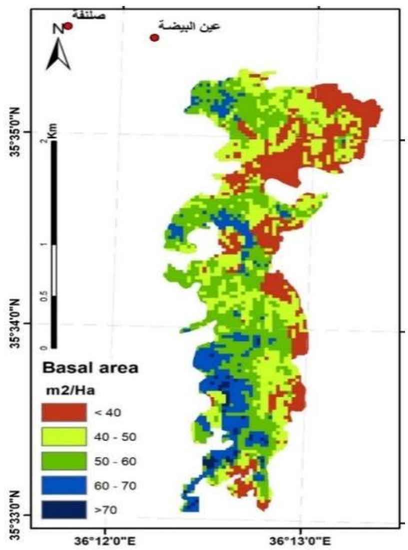
Wood stock map according to the mathematical model
Карта запасов древесины по математической модели



Average heights map according to the mathematical
Карта средней высоты по математическим данным



Average diameter map according to the mathematical model
Карта среднего диаметра по математической модели



Basal area map according to the mathematical model
Карта прикорневой зоны по математической модели

Fig. 4. Growth coefficient maps
Рис. 4. Карты рядов коэффициентов роста

Table 4. The average deviation of the values of the estimated growth factors from the measured ones
Таблица 4. Среднее отклонение расчетных значений факторов роста от значений, полученных в ходе натурных измерений

Growth coefficients	Accuracy Assessment, %	The deviation of the estimated values from the measured ones	
		Average values of deviations	Ratio to the mean, %
Average heights	84	1.5m	11
Average diameters	82	3.8cm	12
Basal area	83	6.2m^2	7.8
Wooden stock	78	88m^3	14

Regression models included all equations used in the research Performed based on terrain aspect, slope, and elevation data, due to the distribution of fir at different heights and directions. Aspect plays an important role in the presence and distribution of cilician fir, which prefers areas with high air humidity, such as the western slopes of the study area.

Also, in all equations, all indicators of natural vegetation were integrated as shown in the (PCA3_Index). As a result of the analysis, the variance in the studied coefficients was explained. The foregoing may explain the absence of individual vegetation indicators in the models for estimating the growth parameters of the fir forest, with the exception of the simple Vegetation index (in the average height model), which expresses in the simplest forms of spectral expressions of the vegetation cover. The contribution of the (PCA4_image bands) of the fourth order of the products of the analysis of the Principal component analysys of the basic bands of the image in the wood stock estimation model is also indicated.

The resulting maps reinforced the results obtained through field surveys in terms of the spatial distribution of the best growth condition. The areas expressing the classes of the highest wood stock values were concentrated in the southwestern parts of the forest, while the classes for the lowest values were concentrated within the values of the two parameters: the wood stock, and the basal area in the northern and north-eastern parts of the forest. As for the values of average heights and diameters, the data of heights and diameters were gotten in the field survey data at the level of the single tree, while the application of the model is concerned with the average of the sample, i.e. the pixel level. It should be noted that this matter shows the importance of integration between field survey data and sensor products, and it lies in this case in the desired benefit from the use of sensor data and the possibility of interpolating data in locations other than the field survey sites, where each pixel is a sample site by itself, while the results of the field survey data constitute the data of the survey sample sites.

Conclusions

The results showed a significant relationship between the studied growth variables and the Sentinel-2 satellite image data, the results of the regression models for growth coefficients were close in terms of the value of the real field data. Therefore, we can conclude that a significant relationship can be detected between the growth parameters of the fir forest and their corresponding spectral reflectance values in the Sentinel-2 image. Thus, it is possible to prove the importance of the indicators used in the research to estimate these parameters, and to obtain accurate values at the level of row diameters, heights, basal area, and wood stock.

It was also revealed that the regression models for the growth coefficients were close in terms of the value of the correlation coefficient. In order to increase the accuracy values that were acquired, it could be possible to test images with a better spectral or spatial resolution. It would also be feasible to apply the temporarily distributed search (over a period of several years) to test the accuracy over time and evaluate growth rates and productivity.

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Information about the authors

Bashar Tobo – Candidate of Agricultural Sciences, Research Fellow at the Centre for Agricultural Research, Latakia, Syria. Research interests – remote sensing of forests and GIS, forest sciences and forest measurements. Author of six scientific publications.

Wael Ali – Candidate of Agricultural Sciences, Associate Professor, Department of Ecology and Forestry, Faculty of Agriculture, University of Tishrin University, Latakia, Syria. Research interests – forest sciences and forest measurements. Author of 34 scientific publications.

Rosa Karmoka – Researcher, General Organization of Remote Sensing (GORS); Expert, the Arab Centre for the Study of Arid Zones and dry Lands (ACSAD), Damascus, Syria. Research interests – Management of Renewable natural resources and Environment. Author of 14 scientific publications.

Ahmed Mahmoud – Candidate of Agricultural Sciences, researcher, the Centre for Agricultural Research, Latakia, Syria. Research interests – Forestry and the environment. Author of seven scientific publications.

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Contribution of the authors:
Bashar Tobo – conceptualization; methodology; software; validation; formal analysis; investigation; resources; data curation; writing – original draft preparation; writing – review and editing; visualization; supervision; project administration; funding acquisition.
Wael Ali – conceptualization; methodology; software; validation; formal analysis; investigation; resources; data curation; writing – original draft preparation; writing – review and editing; visualization; project administration; funding acquisition.
Rosa Karmoka – conceptualization; methodology; software; validation; formal analysis; resources; data curation; writing – original draft preparation; writing – review and editing; visualization; project administration; funding acquisition.
Ahmed Mahmoud – conceptualization; validation; visualization.

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**Оценка таксационных показателей пихты киликийской
в заповеднике «Пихта и Кедр» в Сирии**

Б. Тобо✉, В. Али, Р. Кармока, А. Махмуд
Центр сельскохозяйственных исследований,
Сирия, 424079, Латакия, пригород Тишрина, ул. Буга, 215
bashar.tobo@Tishreen.edu.sy✉

Введение. *Средиземноморские леса обеспечивают местному населению широкий спектр социальных и экономических преимуществ. В частности, это справедливо в отношении лесов Сирии, находящихся под воздействием кризиса, от которого пострадала страна. В связи с этим существует потребность в более точных технологиях инвентаризации и мониторинга лесов для устойчивого управления лесами.* ***Цель исследования*** *– определение продуктивности и характеристик роста деревьев пихты киликийской (Abies cilicica), произрастающих в заповеднике «Пихта и Кедр» провинции Латакия в Сирии.* ***Объект исследования*** *– лес Шух, расположенный в северной части Сирийского прибрежного горного массива, на западном склоне горы Джебель ан-Наби Матта.* ***Методы исследования****. В ходе исследования были использованы технологии дистанционного зондирования и обработки снимков Sentinel с целью оценки некоторых факторов роста леса, для чего были составлены карты, определяющие факторы роста на основе множественного регрессионного анализа связи между переменными исследуемых участков и соответствующими значениями пикселей для всех используемых соотношений и показателей.* ***Результаты и выводы****. Все изученные переменные показали значимую корреляцию R, превышающую 0,75 по запасу древесины, при низкой реакции по плотности, не превышающей 0,33 несмотря на статистическую значимость. Карты рядов коэффициентов роста были составлены с использованием полученного уравнения регрессии для каждого показателя. Самая высокая точность оценки запаса древостоя составила 77 и 72 % для средней высоты. Что касается оценки точности модели, то среднее значение отклонения расчётных значений коэффициентов от полученных в ходе натурных измерений составило 6,08; 9,1; 9,6 и 8–12 % для моделей, оценивающих среднюю высоту, средний диаметр, запас древостоя и прикорневую зону, соответственно.*

Ключевые слова: *Abies Cilicica; заповедник «Пихта и Кедр»; продуктивность насаждения; среднегодовой прирост; воздействие; Сирия; факторы роста; Sentinel*

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Финансирование: настоящее исследование финансировалось в рамках научно-исследовательской деятельности и подготовки баз данных в Сирии, особенно в отношении важных и находящихся под угрозой исчезновения лесных древесных пород.

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Информация об авторах

ТОБО Башар – кандидат сельскохозяйственных наук, научный сотрудник, Центр сельскохозяйственных исследований. Область научных интересов – дистанционное зондирование лесов и ГИС, науки о лесе и лесная таксация. Автор шести научных публикаций.

АЛИ Ваэль – кандидат сельскохозяйственных наук, доцент кафедры экологии и лесного хозяйства, факультет сельского хозяйства, Тишринский университет. Область научных интересов – науки о лесе и лесная таксация. Автор 34 научных публикаций.

КАРМОКА Роза – научный сотрудник, Генеральная организация дистанционного зондирования (GORS); эксперт, Арабский центр аридных зон и засушливых земель (ACSAD). Область научных интересов – управление возобновляемыми природными ресурсами и окружающей средой. Автор 14 научных публикаций.

МАХМУД Ахмед – кандидат сельскохозяйственных наук, исследователь, Центр сельскохозяйственных исследований. Область научных интересов – лесное хозяйство и окружающая среда. Автор семи научных публикаций.

Доступность данных и материалов: данные, представленные в этом исследовании, доступны в статье. Более подробную информацию можно получить по запросу у автора, ответственного за переписку.

Вклад авторов:

Тобо Башар – концепция, методика, программное обеспечение, валидация, формальный анализ, исследование, ресурсы, проверка данных, написание статьи – подготовка исходного текста, написание статьи – чтение и редактирование, визуализация, руководство, администрирование проекта, финансирование.

Али Ваэль – концепция, методика, программное обеспечение, валидация, формальный анализ, исследование, ресурсы, проверка данных, написание статьи – подготовка исходного текста, написание статьи – чтение и редактирование, визуализация, администрирование проекта, финансирование.

Кармука Роза – концепция, методика, программное обеспечение, валидация, формальный анализ, ресурсы, проверка данных, написание статьи – подготовка исходного текста, написание статьи – чтение и редактирование, визуализация, администрирование проекта, финансирование.

Махмуд Ахмед – концепция, валидация, визуализация.

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