Automatic and semi-automatic counting of palm trees from remote sensing images with very high spatial resolution

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ملخص: في الجزائر ، يزرع نخيل التمر في 17 ولاية. وتشير تقديرات الثروة الوطنية إلى وجود أكثر من 18 مليون نخلة مزروعة على مساحة تزيد عن 150000 هكتار. ومع ذلك ، لا توجد معلومات موثوقة عن العدد الدقيق لأشجار النخيل على مر السنين.

غالباً ما تتم عملية عد النخيل يدوياً في الميدان. تعتبر هذه العملية طويلة ومملة بشكل عام بسبب العدد الكبير من المزارع التي سيتم رصدها على الأرض. ولذلك ، فإن أحدث التطورات في تكنولوجيا المستشعرات الجوية عن طريق زيادة القرارات المكانية والطيفية لصور الاستشعار عن بعد ، والتي تمهد الطريق إلى تطبيقات جديدة للاستشعار عن بعد ، تسمح باستخدام الطرق الأوتوماتيكية و / أو شبه الأوتوماتيكية باستغلال صور ذات دقة مكانية عالية لتوفير رصد دقيق للعديد من مزارع النخيل.

لقد جعل العمل المنجز خلال مشروع دراستنا من الممكن تنفيذ منهجية جديدة لكشف وحساب أشجار النخيل بطريقتين مختلفتين:

أول طريقة مقترحة سميت تلقائية او أوتوماتيكية ، تعتمد فقط على معلومات الصورة الطيفية مع افتراض أن جميع أشجار النخيل لها شكل دائري من نصف قطر "R". يرتبط هذا الأخير نسبياً بعمر النخيل ، ويتم استخدامه لتصنيف البكسلات الداخلية لفئة نخيل التمر بشكل مباشر من خلال احترام الحد الأدنى والحد الأقصى المحدد لقيم كل بكسل داخل الدائرة. وسيسمح لنا هذا المنظور بتحديد ، في نفس المزرعة ، نصف قطر أقصى 'R–Max' يقابل أكبر شجرة نخيل في المزرعة ونصف قطر دنيا 'R–Min' يناظر أصغر نخلة.

الطريقة الثانية هي شبه أوتوماتيكية ، لأنها تستخدم العديد من الخطوات المستقلة وأدوات البرمجيات مع بعض التفاعلات البشرية وتثبيت الاعدادات يدويا ، استنادا إلى مفاهيم تحليل الصور المستندة إلى الكائن الذي يقوم على إجراء تجزئة لخلق صورة الأشياء عن طريق الخصائص الطيفية ، والنصية ، والسياقية ، والهندسية لأجسام الصور. تتكون هذه الطريقة من خمس مراحل رئيسية:

1). تقدير معلمات تجزئة باستخدام خوارزمية وراثية ،
2). تنفيذ تجزئة متعددة الدقة ،
3). توصيف المقاطع ،
4). استخراج الأشياء ذات الأهمية حسب قواعد القرار ،
5). عد أشجار النخيل.

من أجل التحقق من فعالية طرقنا ، تم إجراء تقييم دقيق لكشف النخيل والفرز. وهو يعتمد على مقاييس الدقة باستخدام خريطة الحقيقة الأرضية التي تم إنشاؤها عن طريق الترجمة اليدوية ووضع علامات على جميع الأشجار على شاشة الكمبيوتر ، والتي يفترض أنها أشجار نخيل حقيقية ، أي حقيقة الأرض.

النتائج التجريبية مرضية جدا. كما أن طريقتَي كشف وحساب أشجار نخيل التمر المُقترحة ، الأوتوماتيكية وشبه الأوتوماتيكية ، فعالة مع معدل اكتشاف 0.964 و 0.943 ومقاييس F من 0.968 و 0.928 على التوالي.

باختصار ، يمكن استخدام طرقنا المعينة في هذه الدراسة بكفاءة لإنشاء خرائط دقيقة لأشجار النخيل وتحديث المعلومات الجغرافية لنظام مراقبة البيئة خاصةً بالنسبة للزراعة.

الكلمات الأساسية: زراعة النخيل، عد النخيل، صور الأقمار الصناعية، تجزئة متعددة الدقة، شكل دائري، استخراج المعلومات.

Résumé : En Algérie, le palmier dattier est cultivé dans 17 wilayas. Le potentiel phoenicicole est estimé à plus de 18 millions de palmiers dattiers sur une superficie de plus de 150 000 ha. Cependant, Il n'y a pas d'informations fiables sur le nombre de palmiers au cours des années.

Le décompte des palmiers est souvent effectué manuellement sur le terrain. Un tel processus est jugé long et fastidieux en raison du nombre élevé de plantations à surveiller sur le terrain. Par conséquent, l'utilisation de méthodes automatiques et / ou semi-automatiques qui exploitant des images à très haute résolution spatiale, représente une alternative potentiellement intéressante. Pour assurer un suivi précis de nombreuses plantations de palmiers dattiers.

Les travaux réalisésdurant notre projet de fin d'étude ont permis de mettre en œuvre une nouvelle méthodologie pour détecter et compter les palmiers dattiers de deux manières différentes :

La première méthode proposée est dite automatique, basée uniquement sur l'informationspectrale d'image, en supposant que tous les palmiers ont une forme circulaire de rayons « R » différents. Ce dernier est relativement lié à l'âge du palmier dattier et permet de classer directement les pixels internes de la classe de palmier dattier en respectant les seuils minimal et maximal définis pour les valeurs de chaque pixel existe à l'intérieur du cercle. Cette perspective nous permettra de définir, dans la même plantation, un rayon maximum « R-Max » correspondant au plus grand palmier de la plantation et un rayon minimum « R-Min » correspondant au plus petit palmier.

La seconde est dite semi-automatique, car elle utilise de nombreuses étapes et outils logiciels indépendants, avec quelques interactions humaines et un paramétrage manuel, basés sur les concepts de l'analyse d'images basée sur les objets, qui repose sur une procédure de segmentation pour créer des objetsd'image. En utilisantles propriétés spectrales, textuelles, contextuelles et géométriques des objets-images. Cette méthode comprend cinq étapes principales :

1). Estimation des paramètres de segmentation à l'aide d'un algorithme génétique ;

2). Exécution d'une segmentation multi-résolution ;

3). Caractérisation des segments ;

4). Extraction d'objets d'intérêt par des règles de décision ;

5). Comptage des objets d'intérêt (palmiers).

Afin de vérifier l'efficacité de nos méthodes, nous avons procédé à une évaluation de la précision de détection et du comptage des palmiers dattiers. Il est basé sur les mesures de précision utilisant une carte de vérité au sol générée par une photo-interprétation manuelle et un marquage de tous les arbres sur l'écran de l'ordinateur, supposés être des palmiers dattiers réels, c'est-à-dire une vérité au sol.

Les résultats expérimentaux sont satisfaisants. Et les deux méthodes de comptage proposées, automatique et semi-automatique, sont efficaces avec un taux de détection de 0,964 et 0,943 et F-mesures de 0,968 et 0,928 respectivement.

Finalement, les méthodes données dans cette étude peuvent être utilisées efficacement pour créer des cartes précises de plantation de palmiers dattiers et mettre à jour des bases de données géographiques pour le système de surveillance de l'environnement, en particulier pour l'agriculture.

Mots-clés : Culture du palmier dattier, comptage des palmiers dattiers. Imagerie de télédétection, segmentation multi-résolution, forme circulaire, extraction d'objets.

Abstract : In Algeria, the date palm is cultivated at 17 provinces. The Phoenicultural potential is roughly estimated that more than 18 million date palms exist over an area of more than 150 000 ha. However, there is no reliable information on the exact number of palms over the years.

The operation of counting palms is often done manually in the field. Such a process is considered lengthy and tedious generally due to the high number of plantations to be monitored on the ground. Therefore, the latest developments in aerial sensors technology by increasing spatial and spectral resolutions of remote sensing imagery, that clear the way to new remote sensing applications, allow the utilization of automatic and / or semi-automatic methods by exploiting images with Very High Spatial Resolution (VHSR) to provide a precise monitoring of numerous date palm plantations.

The work carried out during our study project has made it possible to implement a new methodology for detecting and counting date palms in two different ways :

The first proposed method is said to be automatic, based solely on spectral image information with the assumption that all palms have a circular shape of different radiuses 'R'. The latter is relatively related to the age of the date palm, and is used to directly classify the inner pixels of the date palm class by respecting minimum and maximum threshold defined for the values of each pixel within a circle. This perspective will allow us to define, in the same plantation, a maximum radius 'R-Max' corresponding to the largest palm tree in the plantation and a minimum radius 'R-Min' corresponding to the smallest palm.

The second one is said to be semi-automatic, because it uses many independent steps and software tools with some human interactions and manually parameterizing, based on the concepts of Object-Based Image Analysis (OBIA) which is based on segmentation procedure to create image objects by means of spectral, textural, contextual and geometrical properties of image objects. This method consists of five main stages :

1). Estimation of segmentation parameters using a genetic algorithm,

2). Executing a multi-resolution segmentation,

3). Characterization of segments,

4). Extracting objects of interest by decision rules,

5). Counting of Palm trees objects.

In order to verify the effectiveness of our methods, the accuracy assessment for the detecting and counting date palms was carried out. It is based on the accuracy measures using ground truth map that was generated by manual interpreting and marking all the trees on the computer screen, which are assumed to be physical real date palm trees, i.e., ground truth. The experimental results are satisfactory. And the two proposed date palm trees counting methods, automatic and semi-automatic, are effective with a detection rate of 0.964 and 0.943 and F-measures of 0.968 and 0.928 respectively.

In sum, our given methods in this study can be efficiently used to create accurate planting date palm trees maps and update geodatabases for environment monitoring system especially for agriculture.

Keywords : Date palm cultivation, Counting date palms. Remote sensing imagery, Multi-resolution segmentation, Circular shape, Objects extraction.

1. Date palm trees tetection and counting using verry height spatail resolution remote sensing imagery

This part describes the workflow of the two developed methods for date palm trees detection and counting using very high spatial resolution remote sensing imagery. The process includes data processing and object extraction, the identification of date palms based on a threshold value defined for the automatic method and, also, on the concepts of Object-Based Image Analysis (OBIA), which is no longer the result of a single algorithm but of a procedure that involves several steps, for the semi-automatic method. Generally, palm groves are characterized by their regular planting, all palms have the same ages (planted in the same period), in this case the palms are visually separable between them, easily, since the palm leaves are not too long.

1.1. Methodology of date palms extraction

The main steps of our methodology for each proposed method are as follows :

1.1.1. Automatic Method

The automatic method is based on spectral image information only with the supposition that all palms in the nature have a circular shape of radiuses 'R' different from one palm tree to others. This radius is relatively related to the age of the date palm, and is used to directly classify the inner pixels to the date palm tree class by respecting a defined minimum and a maximum threshold for the values of each pixel within this circle.

We should define some used parameters :

● **'R-Max'** the maximum radius corresponding to the largest detectable palm tree in the plantation.

● **'R-Min'** the minimum radius corresponding to the smallest detectable palm tree in the plantation.

● **'Step-Value'** represent a fixed value of decreasing of the maximum radius 'R-Max'.

● **'Min_threshold_value'** is the minimum accepted value, to classify a pixel in the date palm class, of the sum of the radiometric values of the three channels (RGB).

● **'Max_threshold_value'** is the maximum accepted value, to classify a pixel to the date palm class, of the sum of the radiometric values of the three channels (RGB).

1.1.2. Semi-automatic Method

For the semi-automatic method, we choose to follow the six key stages :

• ***Apply multi-resolution segmentation.***

• ***Evaluation of the quality of the resulting segmented images.***

• ***Characterization of all resulting objects by computing their spectral, spatial and textural attributes.***

• ***Extraction of the best decision rule.***

• ***Extraction of the objects of interest by the use of decision rules.***

• ***Counting objects of interest.***

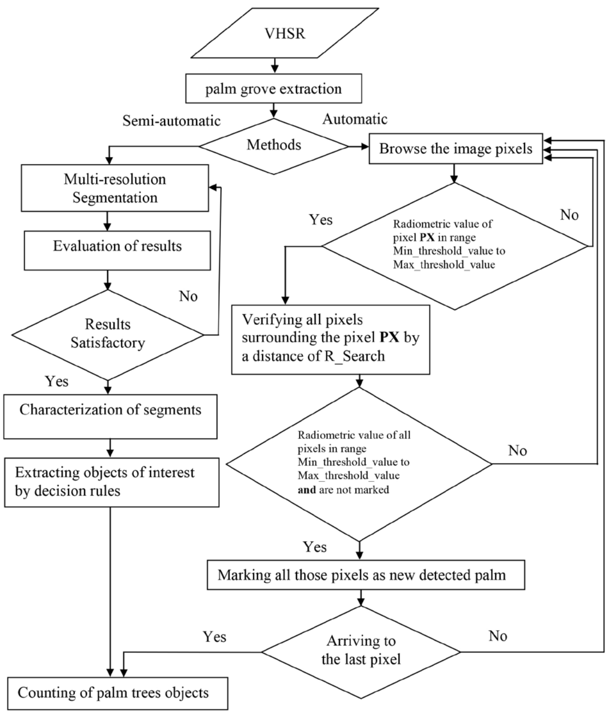


Fig. 1 Flowchart of the two proposed methods for counting of date palm trees using very high-resolution remote sensing imagery

1.2. Image processing and objects extraction

After loading the images for each palm grove separately in the UTM projection, for the semi-automatic method, object-based image classification is conducted using eCognition 8.7.0 software in order to extract different classes shape, exist in the images, by means of the classification hierarchy shown in the diagram.

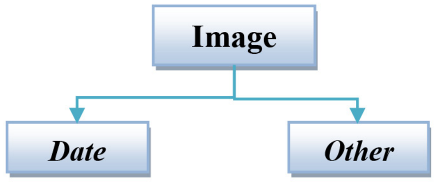


Fig. 2 Classification hierarchy for objects extraction

Based on image segmentation, object-based image classification is the appropriate method for classifying high-resolution remote sensing images [1]. The classification process is executed by defining class descriptors parameters related to spectral, geometric, contextual and textural information of the resulted image segments to classify them by applying for each parameter a threshold process.

1.2.1. Object-Oriented image classification

While pixel-based image classification is based on pixel information (reflectance values), object-based method is based on information obtained from a group of similar pixels called also image objects. Precisely, image objects (also called segments) are groups of pixels that have nearly the same, or in some cases the same, spectral information, shape, size, texture and relationship with neighborhood surrounding pixels where Object-Oriented technique is used to classify these objects by combining both spectral and spatial properties [2], [3]. Consequently, before starting object-based image analysis, for the date palm trees detection and accounting, image segmentation is an essential step in creating the necessary image objects those represents the fundamental unit for further analysis.

1.2.2. Image segmentation

In image analysis, the main goal of image segmentation is to identify structures in the image that are expected to match to the real world objects. The segmentation process of dividing an image into sections (segments) unclassified, those which are representing the basic elements for image analysis, according to some criterions of similarity. These segments are created by grouping pixels that partake homogeneous spectral similarity to generate significant image objects.

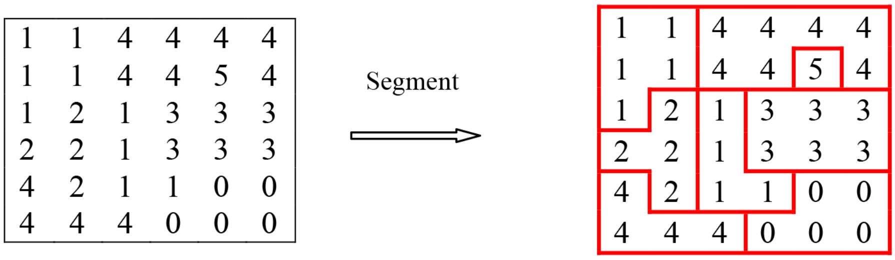


Fig. 3 Principal and result of image segmentation

Generally, two basic strategies used for image segmentation conduction :

- ***Based on cutting big entities into small ones called Top-Down strategy ;***
- ***Based on merging small entities to build big objects called Bottom-Up strategy.***

Using the eCognition software, the multi-resolution segmentation is adopted, giving us the opportunity to define the different parameters names : scale, layer weights (channels), compactness weight and shape weight, as shown in the figure below :

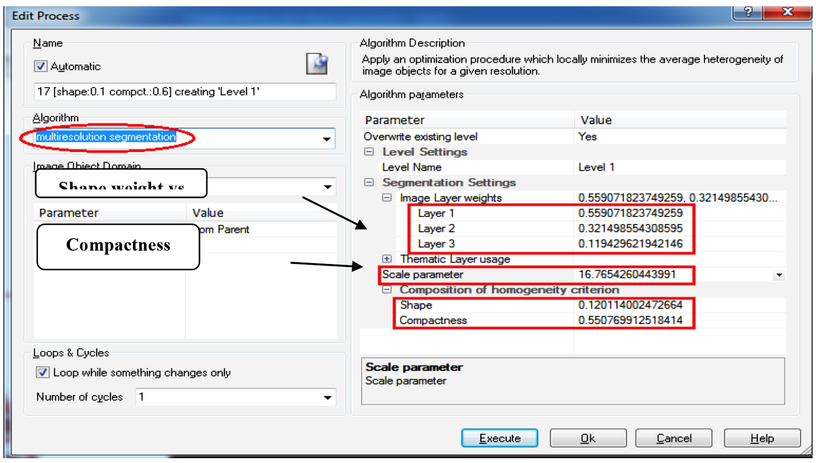


Fig. 4 Multi-resolution segmentation configuration in eCognition software

In summary, to apply image multi-resolution segmentation, the user must define the following parameters that are presented in the (table. 1) blow :

Tab 1. Multi-resolution segmentation parameters

Parameter defined by the user	Objectives and meaning
• Weights related to the channels or image layers	to prefer one or more layers over others
• The scale parameter	the largest scale parameter value avoids overlapping classes because it produces large objects
• The color weight towards the shape	Large value for color weight produces visually accurate objects
• Smoothing weights with towards the compactness	Large smoothness weight to ensure border smoothness of the resulted objects and maintaining non-compact criteria.

2. Experiments and results of date palms remote sensing in Algeria

2.1. Study area and datasets

The selected study area is located in Biskra province in Algeria with the following coordinates : Up Left (708275.6, 3830860.5) and Low Right (713840.1, 3828432.4) based on Universal Transverse Mercator (UTM) projection with WGS 84 Datum.

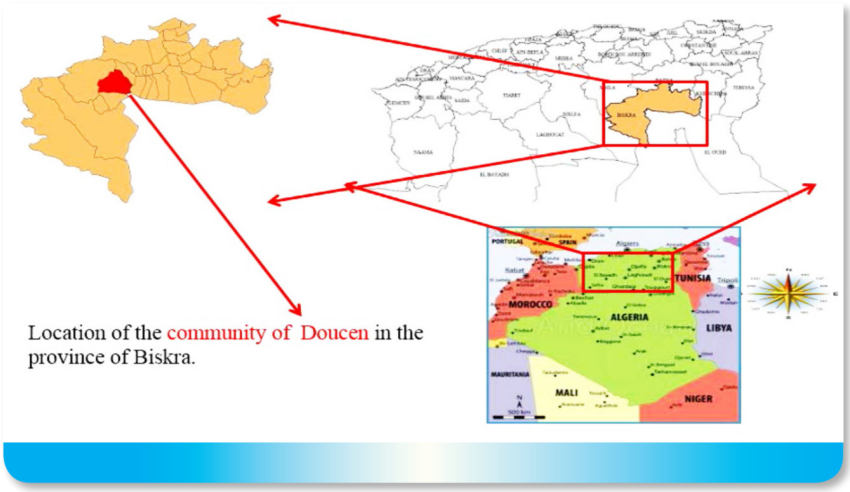


Fig. 5 Study area

Manually digitizes vector layer of date palms is used as reference data (Ground Truth), summarized in the (figure 06), for the quantitative evaluation of the obtained results.

2.2. Software and technologies

All the data used is processed using the ENVI® 5.1 (Exelis Visual Information Solution) software, dedicated to image processing. ArcGIS® 10.0 (ESRI™), dedicated to geographic information system (GIS), to develop spatial approaches and digitization. The SPT® 2.2 tool (Segmentation Parameters Tuner, developed by Computer Vision Lab) as a reference approach based on evolutionary algorithms (genetics), dedicated to the estimation of segmentation parameters. The Weka® 3.6.12 tool (Waikato Environment for Knowledge Analysis) developed by « Machine Learning Group » of the University of Waikato, as a means of automatic generation of decision rules. The Ecognition® 8.7.0 (Trimble) software used for processing based on multi-resolution segmentation, supervised evaluation of results and the extraction of objects of interest by decision rules and finally the Integrated Development Environment (IDE) SharpDevelop 5.1 for the NET framework platform used for the programming and building of the proposed automatic part of our work.

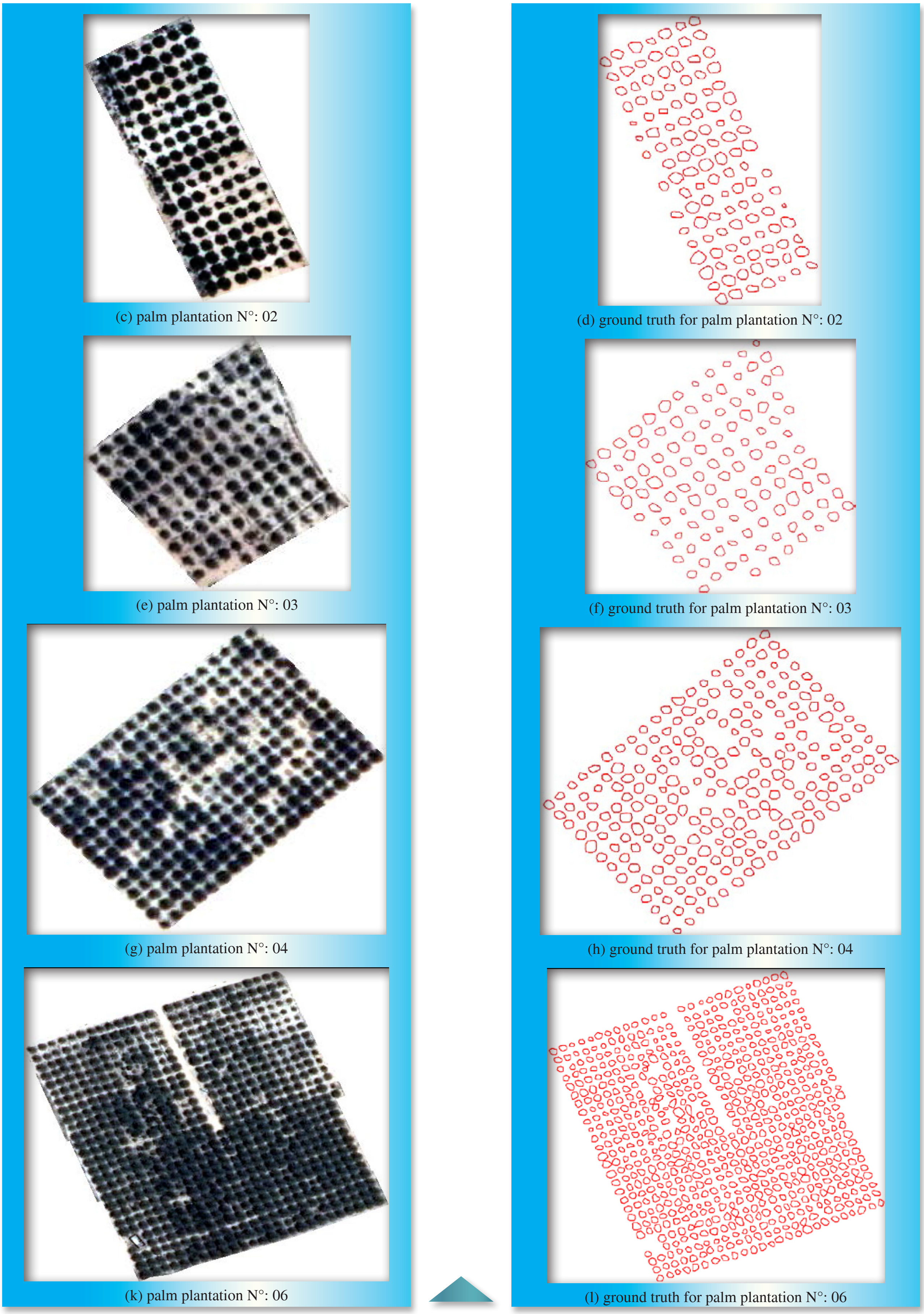


Fig. 6 Images used and Ground truth date palm trees maps

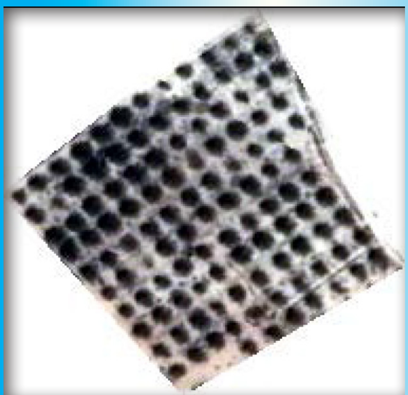
2.3. Experiment one of Automatic proposed method

The first proposed method that is called automatic, based solely on spectral image information with the assumption that all palms have a circular shape of different radiuses 'R'. The latter is relatively related to the age of the date palm, and is used to directly classify the inner pixels to the date palm tree class by respecting a minimum and a maximum threshold defined for the values of each pixel within this circle. The principal idea of this method is similar to the tree crown delineation technique used by [4].

From the below (figure 07), date palm trees are identified successfully and separated from other classes such as background and water basin. Also, visual check and examination by naked eye demonstrate that the proposed automatic date palm trees detection and counting method based on spectral image properties and with the assumption that all palms have a circular shape of different radiuses successes to detect and extract the desired date palm trees map. Nevertheless, the accuracy assessment of this result must be completed in order to evaluate the efficiency of the proposed approach to detect and count date palm trees.

(c) palm plantation N°: 02

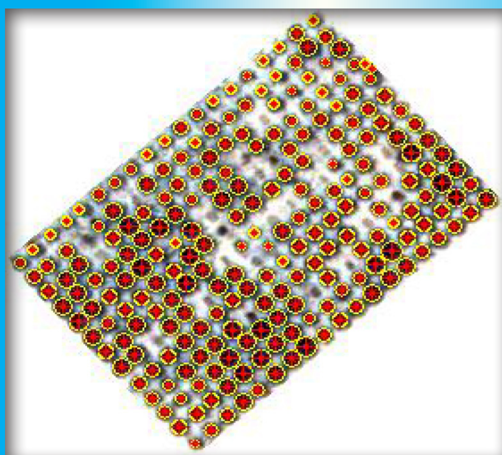
(d) results obtained for palm plantation N°: 02



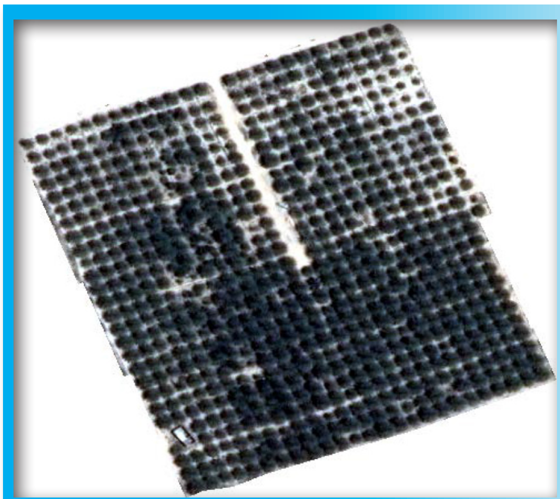
(e) palm plantation N°: 03

(f) results obtained for palm plantation N°: 03

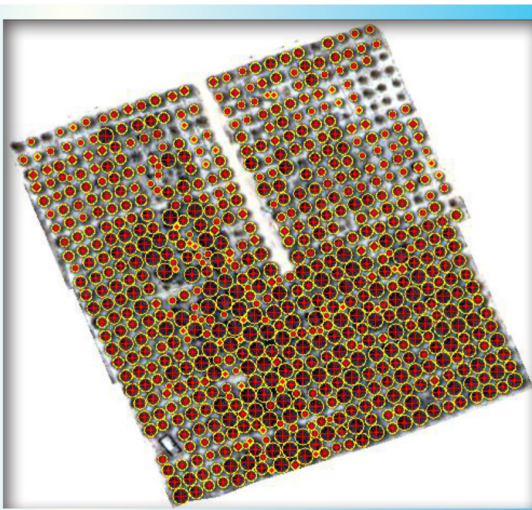
(g) palm plantation N°: 04



(h) results obtained for palm plantation N°: 04



(k) palm plantation N°: 06



(l) results obtained for palm plantation N°: 06

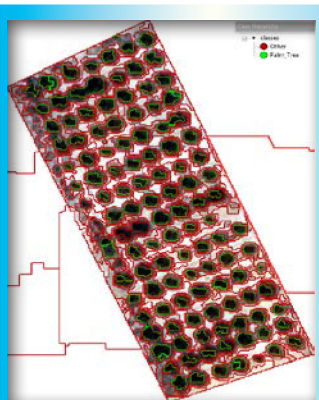
Fig. 7 Images used and results obtained by the automatic method

2.4. Experiment two of Semi-automatic proposed method

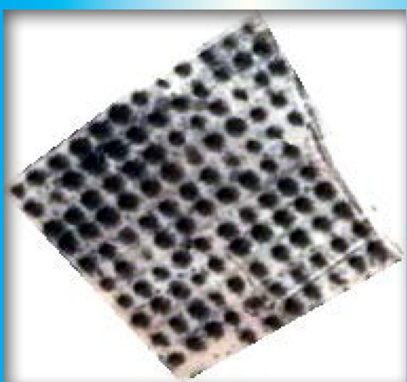
After data preparation process, including radiometric corrections and subset images extraction for each palm plantation individually, objects extraction must be performed to extract image features shape using eCognition 8.7.0 software.

From the below (figure 08), date palm trees are identified successfully and separated from other classes by using our proposed semi-automatic method. Also, visual check and examination by naked eye demonstrate that the proposed automatic date palm trees detection and counting method based on the concepts of Object-Based Image Analysis successes to detect and extract the desired date palm trees map. Nevertheless, the accuracy assessment of this result must be completed in order to evaluate the efficiency of the proposed approach to detect and count date palm trees.

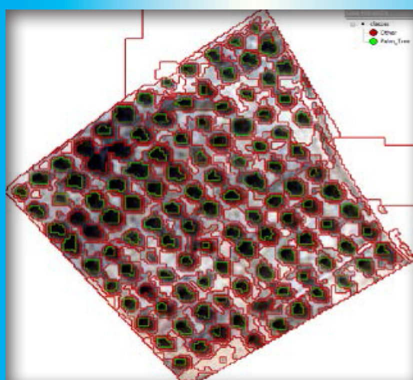
(c) palm plantation N°: 02



(d) results obtained for palm plantation N°: 02



(e) palm plantation N°: 03



(f) results obtained for palm plantation N°: 03

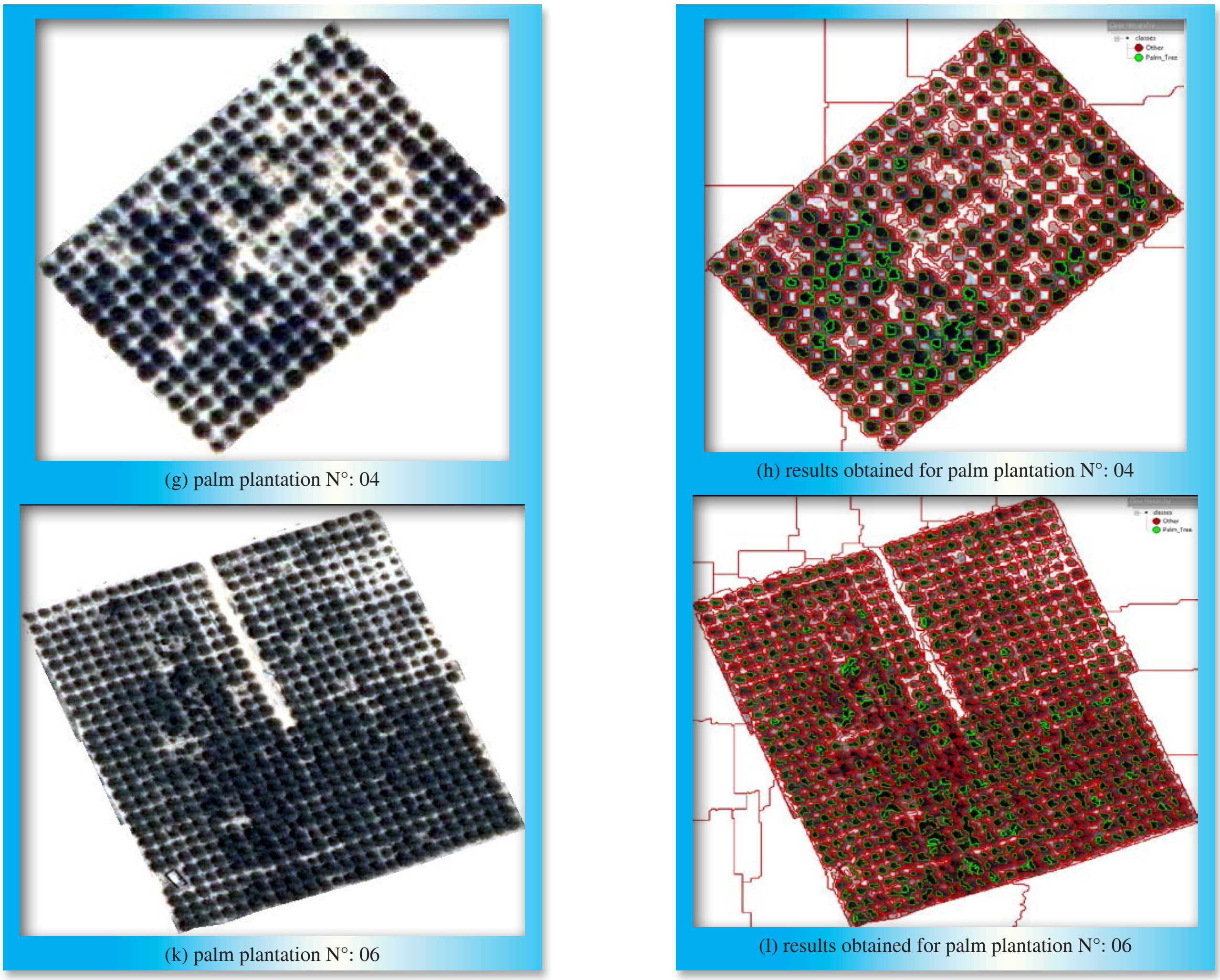
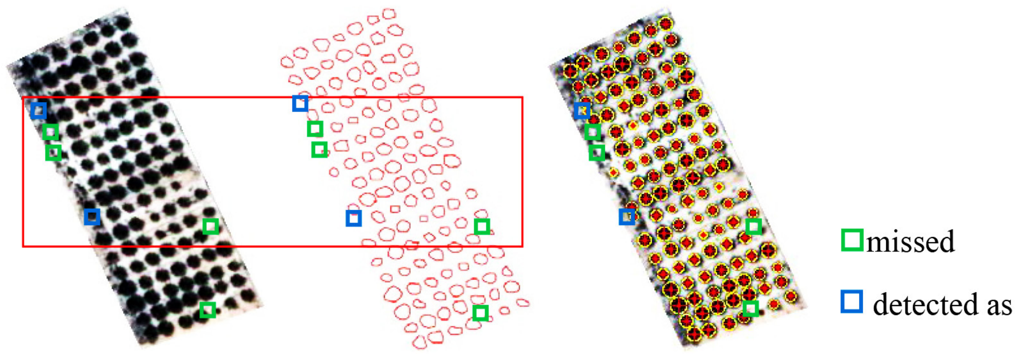


Fig. 8 Images used and results obtained by the semi-automatic method

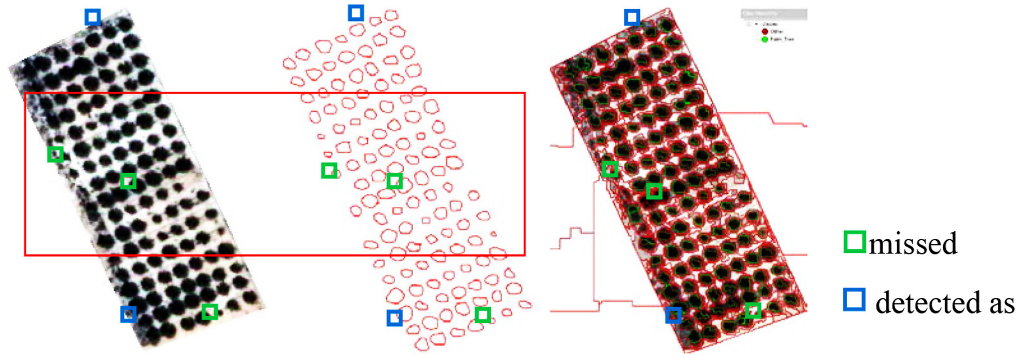
2.5. Accuracy assessment

The accuracy assessment aims to evaluate the efficiency of the automatic and semi-automatic proposed methods to detect and count date palm trees using a very high spatial resolution images comparing to the references data, which are obtained by manually two dimensional digitalization on screen with the same images used in our proposed methods, by a qualified human operator.



(a) palm plantation (b) ground truth (c) results obtained

Fig. 9 Example of false alarm in the automatic method



(a) palm plantation (b) ground truth (c) results obtained

Fig. 10 Example of false alarm in the semi-automatic method

The resulted maps, (figures 09 & 10) as examples, show that our proposed automatic and semi-automatic methods present false alarm, some date palm trees are missed and some other objects detected as date palm trees, in detecting date palm trees. which affect the accuracy of the counting results later.

In order to evaluate the performance of our proposed automatic and semi-automatic methods, we compare the obtained results of detecting and counting process, from both mentioned methods, with a reference data map generated by manual interpretation and digitalization. The quantitative comparison of the obtained results is achieved by means of three different parameters, those reflect the performance of objects detection strategy, namely precision, recall and the F-measure [5]. These metrics are defined according to the subsequent equations [6] :

$$\textbf{Precision} = \frac{|TP|}{|TP| + |FP|} = \frac{\text{number of correctly detected date palm trees}}{\text{number of all detected date palm trees}} \quad (1)$$

$$\textbf{Recall} = \frac{|TP|}{|TP| + |FN|} = \frac{\text{number of correctly detected date palm trees}}{\text{number of date palm trees in the ground truth data}} \quad (2)$$

$$\textbf{F} - \textbf{measure} = \frac{2 * \textbf{Precision} * \textbf{Recall}}{\textbf{Precision} + \textbf{Recall}} \quad (3)$$

Where :

True Positives (TP) : correctly classified pixels as positive, i.e. pixels classified as date palm tree by the algorithm and classified as date palm tree in the reference map.

False Positives (FP) : not correctly classified pixels as positive, i.e. pixels classified as date palm tree by the algorithm and not classified as date palm tree in the reference map in other words it is really something else.

False Negatives (FN) : not correctly classified pixels as negative, i.e. pixels not classified as date palm tree by the algorithm and classified as date palm tree in the reference map.

The operator |.| : represents the number of elements of each category (set cardinality).

Therefore, after identifying the number of date palm trees objects for each palm plantation the three different parameters precision, recall and the F-measure are calculated to evaluate the degree of agreement between the ground truth data and counting of date palm trees methods under study as shown in the tables below :

Tab 2. Performance evaluation of the automatic proposed method

plantation N°:01	Number of Detected date Palm Tree	Ground Truth	False Positive	False negative	Precision	Recall	F-Measure
01	91	91	0	0	1.000	1.000	1.000
02	114	116	2	4	0.982	0.966	0.974
03	113	115	3	5	0.973	0.957	0.965
04	225	228	2	5	0.991	0.978	0.985
05	102	102	2	2	0.980	0.980	0.980
06	679	664	39	20	0.943	0.970	0.956
Total	1324	1316	48	36	0.964	0.973	0.968

Tab 3. Performance evaluation of the semi-automatic proposed method

plantation N°:01	Number of Detected date Palm Tree	Ground Truth	False Positive	False negative	Precision	Recall	F-Measure
01	91	91	9	5	0.901	0.943	0.921
02	117	116	7	6	0.940	0.948	0.944
03	106	115	0	9	1.000	0.922	0.959
04	233	228	17	12	0.927	0.947	0.937
05	104	102	9	7	0.913	0.931	0.922
06	620	664	31	75	0.950	0.887	0.917
Total	1271	1316	73	114	0.943	0.913	0.928

3. Conclusion

The results obtained by the application of our two extraction methodologies were evaluated using the notion of detection rate and the F-measure function, so a comparison was made between them. According to the counting statistics obtained, and by comparing the different extraction results with the manual digitization of date palms, by the ArcGIS® software, it is noted that the two methodologies give very good and so close counting results. also, the automatic method is evaluated better than the semi-automatic method in our studied areas.

In general, the application of our approaches to VHSR images has given satisfactory results comparable to other results from the methods found in the image processing literature.

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