Crop Monitoring as an

E-agricutural tool in Developping Countries

CROP AREA ESTIMATION

Report on accuracy assessment for the spatial extrapolation for Morocco

Reference: E-AGRI_D53.2. Report on accuracy assessment for the spatial extrapolation in Morocco

Authors: Hamid MAHYOU, Riad BALAGHI, Redouane ARRACH, Mostafa TAHRI, Hafida BOUAOUDA, Soufiane MESTARI, Qinghan DONG, Herman EERENS.

Version: 1.0

Date: 6/03/2014

DOCUMENT CONTROL

Signatures

Authors: **Hamid MAHYOU, Riad BALAGHI, Redouane ARRACH, Mostafa TAHRI, Hafida BOUAOUDA, Soufiane MESTARI, Qinghan DONG, Herman EERENS.**

Reviewer(s) :

Approver(s) :

Issuing authority :

Change record

Release	Date	Pages	Description	Editor(s)/Reviewer(s)
1.0	**6/03/2014**			
2.0	Xx/xx/xxxx			

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

In Morocco, cereals (bread wheat, durum wheat and barley) constitute the basis for food security and are cultivated mostly under rainfed conditions. Area of the three main cereals in Morocco (soft wheat, durum wheat and barley) was estimated based on two methods: Area frame sampling and remote sensing methods. Five test provinces of Morocco were selected as test sites: Settat, Berrechid, Benslimane, Khouribga and Meknes. Agriculture is the most dominant activity in these provinces, which can be representative of cereal behavior in all over the country.

Supervised classification was undertaken based on inexpensive high resolution images of 30 meters spatial resolution (Landsat TM5 and ETM+7) and using an available detailed croplands mask provided by The Direction of Strategy and Statistics (DSS) of the Ministry of Agriculture. The methodology was tested for four contrasted cropping seasons (2006-2007, 2010-2011, 2011-2012 and 2012-2013).

Secondary Sampling Units were used as training and testing sets for this supervised classification. So, half of the fields were randomly selected for training the classifier and the second half was kept for validating classification accuracy. However, to improve the accuracy of cereals classification derived from the supervised classification of Landsat TM5 / ETM7 images, we introduce in the decision process tree classifier that resulted from supervised classification and the land cover classes developed in the stratification method.

Area Frame Sampling is provided at provincial level, based on sub-provincial sampling survey. The coefficient of variation (CV) is used as a measure of the precision of the survey (the lower CV, the better).

Results show that the methodology based on low resolution images and a detailed crop mask was able to provide accurate estimates of cereals area (wheat and barley confounded) in the selected provinces and can be extended to all over Morocco for operational area estimation, provided further verifications.

1. Introduction

In Morocco, cereals (bread wheat, durum wheat and barley) constitute the basis for food security and are cultivated mostly under rainfed conditions (in more than 92% of cereal lands). Cereal yield forecasting has already been addressed successfully in Morocco, thanks to previous studies (and the E-AGRI project, while area estimates of the cereals are still problematic. Monitoring and estimating cereals area in Morocco is then required in order to estimate cereal production. An accurate estimation of cereal production will contribute to plan in advance for imports and then strengthen food security issue.

The total area of cereals has steadily increased since 1980, at an average rate of 39,600 hectares/season. This increase was mainly the result of increased soft wheat area, boosted by the large scale state promotion of this crop, launched in 1985-1986.

Since the 1970s and 1980s, application of remote sensing technique in crop acreage estimation has becoming increasingly dominant. Crop acreage estimation using remote sensing provides timely and reliable information. Efficient images processing and classification provide the so called crop area estimates by remote sensing. Nowadays, methodologies combining ground and earth observation data are commonly adopted. Research has been conducted to use the medium resolution satellite data to assess the crop acreage early in the growth season. These coarse resolution sensors have the advantage of low costs, high availability to avoid the cloud disturbance. It is expected that this combined approach will retrieve the best area estimate.

This component of the project introduces on accuracy assessment for the spatial extrapolation for Morocco.

2. Study areas in Morocco

2.1 Chaouia-Ouardigha region

Chaouia-Ouardigha is one of the sixteen regions of Morocco. It is located in the north-central part of Morocco, covering an area of approximately 16,510 km^2 (***Figure 1***). The four administrative provinces of this region were selected: Benslimane, Berrechid, Settat and Khouribga.

The region is characterized by a semi-arid climate, moderated by the proximity of the Atlantic Ocean on its western coastal side. The average annual rainfall across the province is 350 mm, with high inter-annual variability. As in other parts of the country, As well, there is increasing aridity gradient from North to South and from west to east, and precipitations are concentrated around two seasons: November till December and February till March. The annual average temperature is 17.5 °C in Berrechid, 17.9 °C to 19.5 °C in Settat, for example. Also, there is an increasing temperature gradient from north to south.

In this region, most of the lands are covered by rainfed agriculture (69%), forests (12%) and rangelands (11%). Most of the lands of the selected provinces are covered by rainfed agriculture: Berrechid (88%), Settat (74%), Khouribga (61%), Meknes (58%) and Benslimane (53%).

Agriculture is the most dominant activity in the region, as it employs 47% of the population (5% urban, 71% rural areas), and contributes to 16% of the national cereal production. Cereals cover 66% of cropped lands, whereas legume crop does not exceed 4%.

Seven classes of soils where identified in the region. These are the raw mineral soils, low developed soils, Vertisols, calcimagnesic of soil, isohumic soil, fersiallitic soils and waterlogged soils. The calcimagnesic soils occupy the largest area of the region (31%) followed by soil unsophisticated (23.4%). The lower surfaces are occupied by soils with ferric oxide (7%) and Vertisols (7%).

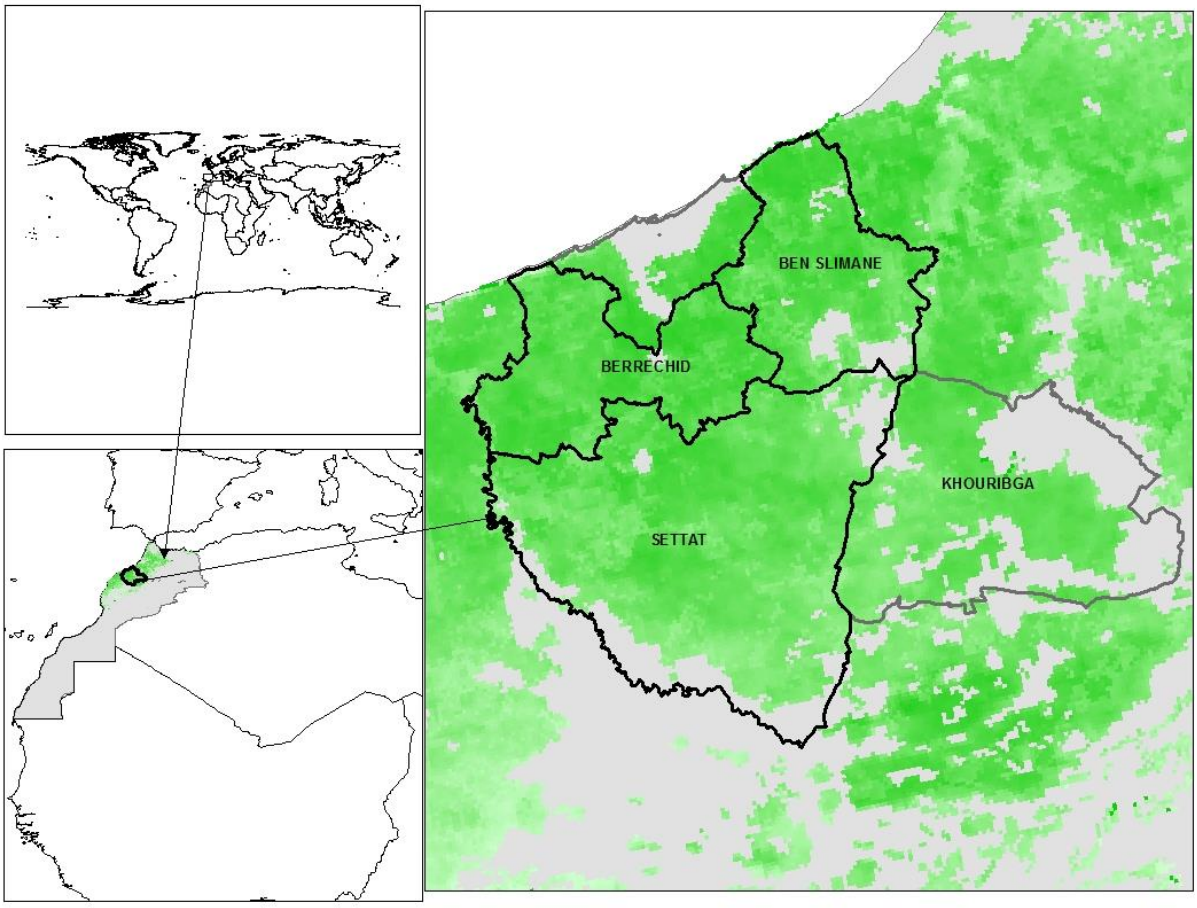

Figure 1: Chaouia-Ouardigha test areas (boundaries in black). The areas cover a significant part of the agricultural lands of Morocco (in green). Agricultural lands were extracted from Global Land Cover 2000 map (GLC2000 version 5.0, Mayaux et al., 2004).

2.2 Meknes province

Meknes province is located north-west of Morocco (33 ° 53 '36 N, 5 ° 32' 50 W) covering an area of approximately 179,000 hectares (***Figure 2***). It is located on the Saïs plateau, between the Middle Atlas and Rif mountains. Meknes is qualified as an area with a high agricultural potential and is positioned among favorable regions of Morocco. The agricultural area is 149,500 hectares, divided into 79,243 plots. Most of the croplands are rainfed (58%), and few are irrigated (10%).

The climate in Meknes province is sub-humid, with cool and rainy winter and with hot and dry summer. In a normal season, the average rainfall is about 450 mm which is favorable for most crops, including cereals, legumes and industrial crops. The province undergoes cycles

of drought and irregular rainfall as in all over the country. Rainfall is concentrated periods of October till March with a maximum in December. From May to September the season is dry.

Agriculture in the province is characterized by small-scale farming, with 75% of the farms' area is less than 5 hectares and only 1.3% of the farms area is over 50 hectares. Cereals production is characterized by a significant interannual variability mainly related to climatic rainfall variability.

Meknes soils are constituted by limestone, and are characterized mainly by calcimagnesic rendzinas and brown calcareous soils groups, varying in thickness depending on the depth of the substrate and the old and recent manifestations of anthropogenic erosion and runoff are the main types of soil inventory.

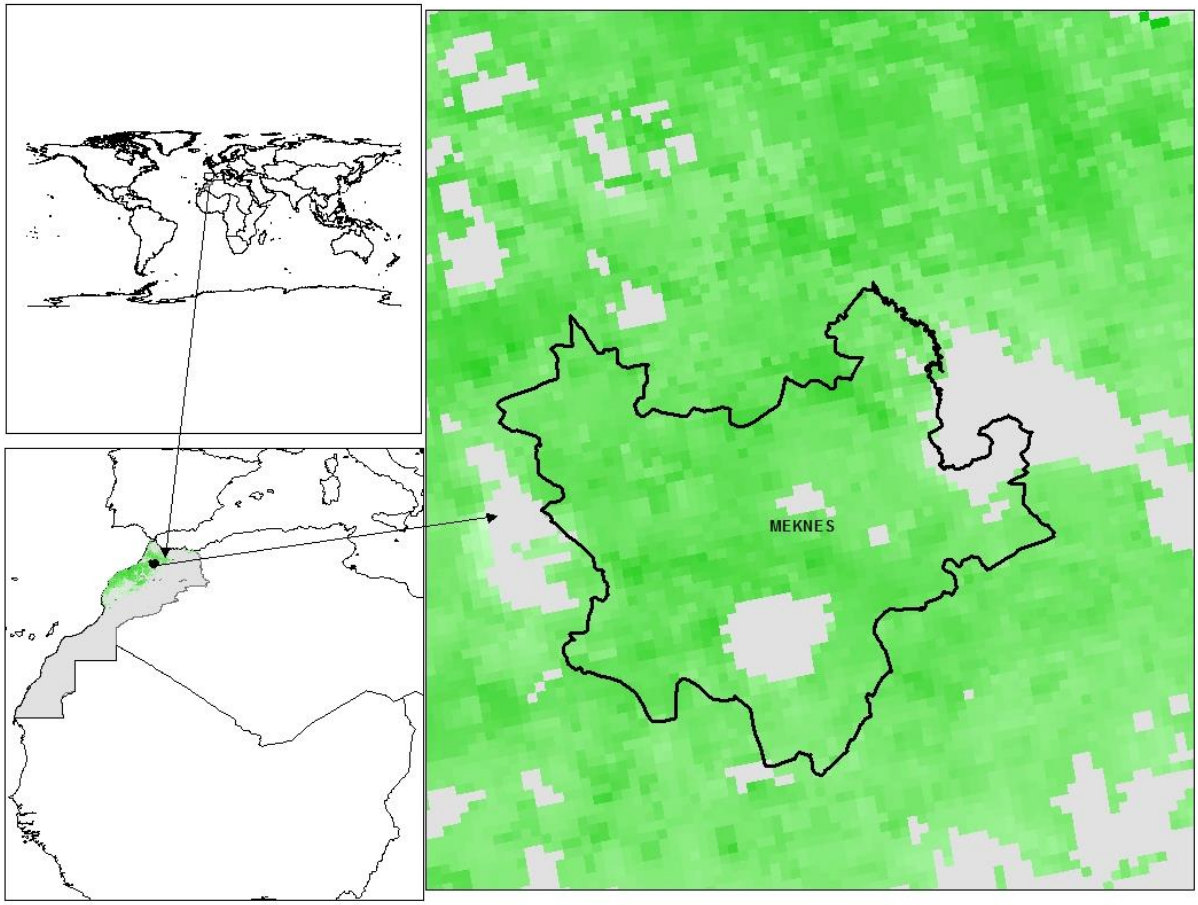

Figure 2: Meknes test areas (boundaries in black). The areas cover a significant part of the agricultural lands of Morocco (in green). Agricultural lands were extracted from Global Land Cover 2000 map (GLC2000 version 5.0, Mayaux et al., 2004).

3. Accuracy assessment of Area Frame sampling method

The two studied regions were simultaneously surveyed according Area Frame Sampling (AFS) schemes during the project by the Direction of Strategy and Statistics (DSS) of the Ministry of Agriculture. The Area frames are the foundation to the agricultural statistics program of the Ministry of Agriculture

The procedures used in this study to develop and sample area frames for agricultural surveys involve many steps, which have been developed to provide crop statistics at the province level. The methodology consists in 3 main steps: The stratification, the zoning and the sampling.

The precision of the survey estimates or statistics can be substantially improved by dividing the croplands in each province into homogeneous groups or strata and then optimally allocating the total sample to the strata. The basic stratification employed involves: (1) dividing the land into land-use strata such as rainfed cultivated land, urban areas and rangeland etc., and (2) further dividing each land-use stratum into substrata by grouping areas that are agriculturally similar.

In our study, the stratification consisted in delineating the land cover classes, called "Strata". Ten strata where defined by DSS for Morocco. These 10 strata were digitized using GIS, based on aerial photography, topographic maps, orthorectified SPOT color images (2.5 meters spatial resolution) acquired in year 2008 and, other thematic maps covering all agricultural areas of Morocco.

A fixed ID number was given for each of the strata. Natural constraints (agro-pedo-climatic and topography conditions) that could potentially influence crop production and livestock productivity were taken into account to improve the stratification. A software application has been developed by DSS in order to automatically integrate natural constraints in the stratification (see deliverable 5.31).

The zoning is the procedure for delineating the Primary Sampling Units (PSU) and the Secondary Sampling Units (SSU). The zoning is a three steps procedure:

- First step: It consists in dividing each stratum in regular rectangles, called Primary Sampling Units (PSU). The size of the rectangles is defined of each stratum.
- Second step: It consists in correcting the borders of the PSU so that they match with natural boundaries (roads, rivers, lakes, etc.).

- Third step: It consists in dividing the PSU in regular squares, also called "segments" or Secondary Sampling Units (SSU).

The selection of primary sampling units was performed according to a random probability method proportional to size. The secondary sampling units were performed using a simple random sampling. Once the primary units were selected, a subdivision of these units or sub-units segment was performed.

Table 1 presents an example of AFS scheme in the Chaouia-Ouardigha region. The size of the samples is decided based on an optimal decision process, which depends on available financial resources and targeted accuracy. In Morocco, the size of samples has been decided based on ground experience and on the national agricultural census of Morocco published in 1994. To test the method we have limited the dimensions of the study to stratum 10 (Rainfed agricultural lands) of the various study sites. The size and number of samples in the stratum 10 are given in the ***Table 1***. The size of these segments in strata 10 is 30 hectares.

Table 1: Example of size and number of samples in the stratum 10 (Rainfed croplands) in the test areas.

PROVINCE	STRATUM	STRATUM AREA (hectares)	SAMPLE SIZE
Benslimane	**10**	**133532**	**36**
Khouribga	**10**	**246345**	**48**
Settat	**10**	**478739**	**81**
Berrechid	**10**	**222495**	**48**
Meknes	**10**	**104086**	**18**

3.1 Field data investigation

Field data were collected from ground surveys by DSS and covered the two studied regions, during seasons of 2010-2011, 2011-2012 and 2012-2013, in Chaouia-Ouardigha region, while the data were collected during seasons of 2011-2012 and 2012-2013 in province of Meknes.

As mentioned, the survey is mainly performed by experienced staff members from DSS, one of which has good knowledge of GPS, mapping and cropping practices in the study areas.
The ground survey was conducted in February and March and field locations were geo-referenced using a global positioning system. The numbers of sample segments adopted is

81, 48, 48, 36 and 18 in Settat, Khouribga, Berrechid, Benslimane and Benslimane, respectively. Also, the number of SSU samples used for each studied province was: 1,193, 574, 478, 448 and 419 in Settat, Benslimane, Berrechid Khouribga and Meknes, respectively.

3.2 Accuracy Assessment of Area Estimates based on Area Frame sampling method

The results from the field survey were used directly as check area estimates, without the interference of remote sensing. According to sampling theory, the population mean estimate "Y*" of the area estimator for a given terrain class is simply the weighted mean of the stratum means "Ys", where the relative areas function as weights "ws":

$Y^* = \Sigma ws.Ys = \Sigma (Ns,i/Ni).Ys$ (summation over the Ns strata)

Where: "Ni" is the total number of segments; "Ns", is the number of segments in stratum "s" and s=1→Ns, the number of strata.

Thus, the estimation of cereal acreage method is based on four key elementary statistics:

- Y (s): area of stratum s;
- Y_T: total area observed in the sample;
- Y_{cer}: Surface observed on cereals in the sample;
- CE: Extrapolation coefficient which is equal to the ratio of the area of stratum (s) divided by the total area observed in the sample;

After determining these elementary statistics, the estimate of the area of cereals (Yc) in stratum "s" is the followings: $\mathbf{Y_c = Y_{cer} * CE = Y_{cer} *(Y (s)/ Y_T)}$

Likewise, the coefficient of variation **CV=σY*/Y*** is used as a measure of the precision of the survey (the lower CV, the better). Thus, the variance ($\sigma^2 Y^*$) of this estimator is computed as: $\mathbf{\sigma^2 Y^* = Var(Y^*)= \Sigma(Ns,i/Ni)^2.Var(Ys) = \Sigma(Ns,i/Ni)^2.(\sigma^2 s/ns).(Ns,i-ns)/(Ns,i-1)}$ with ns the number of segments selected in stratum s, so ns/Ns,i is the sampling density. The within-stratum variance of the target variable $\sigma^2 s$ can be defined from the sample.

Cereals areas estimation based on Area Frame Sampling method (AFS) are shown in the ***Table 2***, during seasons of 2011-2012 in the five studied provinces. The test areas are composed by the strata 10 (rainfed cropland), covering 498,917; 270,288; 222,120; 133,570 and 104,086 hectares in Settat, Khouribga, Berrechid, Benslimane and Meknes provinces, respectively. Settat province is the most important province in term of area compared to Khouribga, Meknes, Berrechid and Benslimane provinces.

The proportion of the three cereals (soft wheat, durum wheat and barley) differs between the studied provinces. Barley is the most frequent crop in Khouribga, while soft wheat is the major crop in Benslimane, Berrechid and Meknes. In Settat, the three species are in almost the same proportion.

Likewise, the results point out similar trends of significant difference of cereals area in all provinces during season of 2011-2012. In Berrechid and Benslimane provinces results indicate that cereals area was important in 2011-2012.

Field area estimates of the three cereals (soft wheat, durum wheat and barley), based on AFS during seasons of 2011-2012 are the followings:

- Berrechid: 146,644 hectares;
- Settat: 362,177 hectares ;
- Berrechid: 76,811 hectares ;
- Khouribga: 185,443 hectares.

Concerning Meknes province, area estimates are 55,454 hectares for season of 2011-2012

Table 2: Area estimates (Hectare) for cereals (soft wheat, durum wheat and barley) in the studied provinces during season of 2011-2012.

2012	Y (s)	Y_T	CE	Y_{barley}	$Y_{durum\ wheat}$	$Y_{soft\ wheat}$	Barley	Durum wheat	Soft wheat	All 3 cereals
BENSLIMANE	133570	2490	54	204	349	878	**10962**	**18740**	**47109**	**76811**
BERRECHID	222120	2182	102	145	629	667	**14750**	**64024**	**67870**	**146644**
KHOURIBGA	270288	2247	120	972	155	414	**116911**	**18680**	**49852**	**185443**
SETTAT	498917	3913	128	1142	911	787	**145662**	**116110**	**100405**	**362177**
MEKNES	104086	1221	85	36	33	582	**3061**	**2806**	**49587**	**55454**

Y (s): Area of stratum s; Y_T: Total area observed in the sample; Y_{cer}: Area observed on cereals in the sample; CE: Extrapolation coefficient.

An example of precision parameters of the area sampling concerning cereals in the Chaouia-Ouardigha region during 2012 is mentioned in ***Table 3***.

Table 3: Accuracy assessment for cereals (soft wheat, durum wheat and barley), in the studied provinces during season of 2011-2012.

Parameters	Settat	Berrechid	Benslimane	Khouribga
Cereal area by segment	26.78	24.87	33.33	25.89
Standard deviation	8.35	6.92	20.05	9.66
Number of segment per sample	81	48	36	48
Precision in % (CV)	6.80%	7.86%	19.65%	10.55%

4. Accuracy Assessment of Remote Sensing method.

4.1 Data sets and method

The main data used in the remote sensing method included Landsat 5 thematic mapper and Landsat7-ETM satellite images. This classical type of high resolution images (30 meters) is detailed enough to discern the major individual fields. Hence, the acquisition costs are considerable, especially in terms of price/km². Landsat7-ETM scenes can be downloaded for free from internet. However, Landsat7-ETM forms an important exception. Since May 2003 the ETM-scenes are perturbed by a defect of the scan line mirror, which results in a lot of missing values, especially near the raw image edges. But in spite of these "SLC-off errors" (Scan Line Corrector), ETM is still extremely interesting because on the average the defect only affects 20% of the pixels (80% of each registration is still useful). Even more, USGS has developed methods for correcting bad lines. The methods developed can be reviewed on http://landsat.usgs.gov/using_Landsat_7_data.php.

Thus, a number of Landsat TM5 / ETM7 images which path / row are 201/036, 202/036, and 202/037 (***Figure 3***) of 2007, 2011, 2012 and 2013 years, taken on several periods during years were used to cover the different study areas. All data sets were radiometrically calibrated according to the method put forward by (Chander and Markham, 2003). Subsets of satellite images with UTM projection (WGS 84 datum) were re-projected to the Moroccan Lambert conformal conic projection. However, images taken in February or in March were found to be best discriminating between different landcover types, as it is the period when pick of vegetation occurs. The image classification system used in this study aims at converting spectral data into land cover classes. First, a parametric classification was performed, based on a maximum likelihood algorithm (Foody, 1992; Maselli et al., 1994), using six spectral bands (1, 2, 3, 4, 5, and 7) found to be best discriminating.

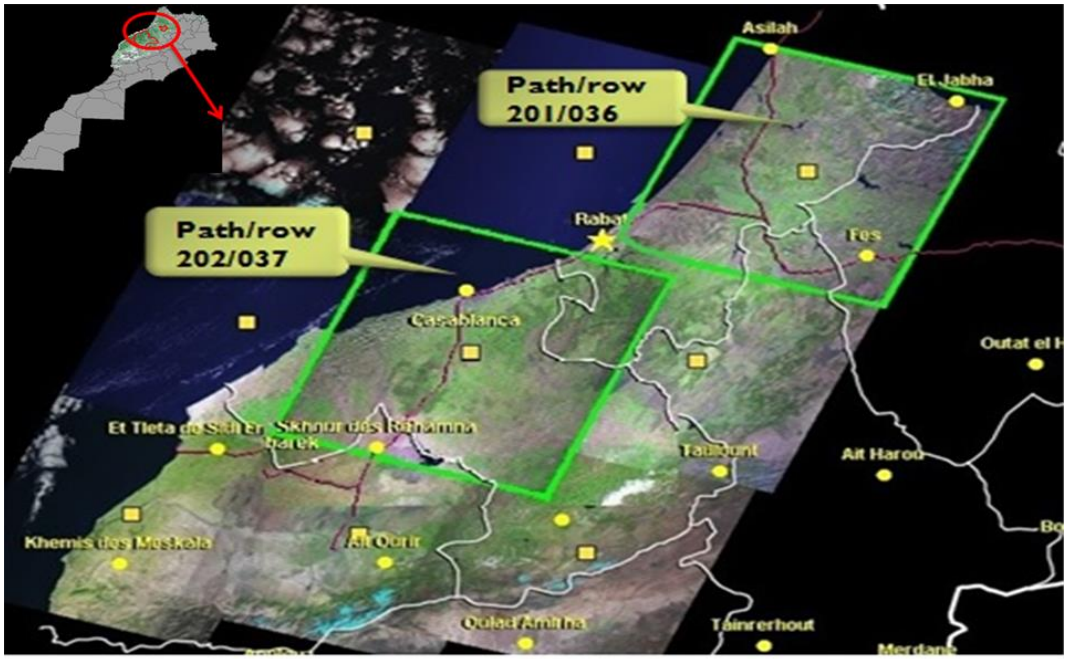

Figure 3: Example of Landsat7-ETM scenes, registered for the two "frames" covering the "study areas": the 202/037 scene covers Chaouia-Ouardigha region and the 201/036 covers the Meknes provinces. Source: GLOVIS website.

Secondary Sampling Units (SSU) combined with visual interpretation from Landsat TM5 / ETM7 images were used as training and testing sets for supervised classification. So, half of the fields were randomly selected for training the classifier and the second half was kept for testing the classification accuracy. However, to improve the accuracy of cereals classification derived from the supervised classification of Landsat TM5 / ETM7 images, we introduce in decision tree classifier the results of supervised classification and the land cover classes developed in the stratification method. Thus, the general approach for the classification of Landsat images is illustrated in ***Figure 4***.

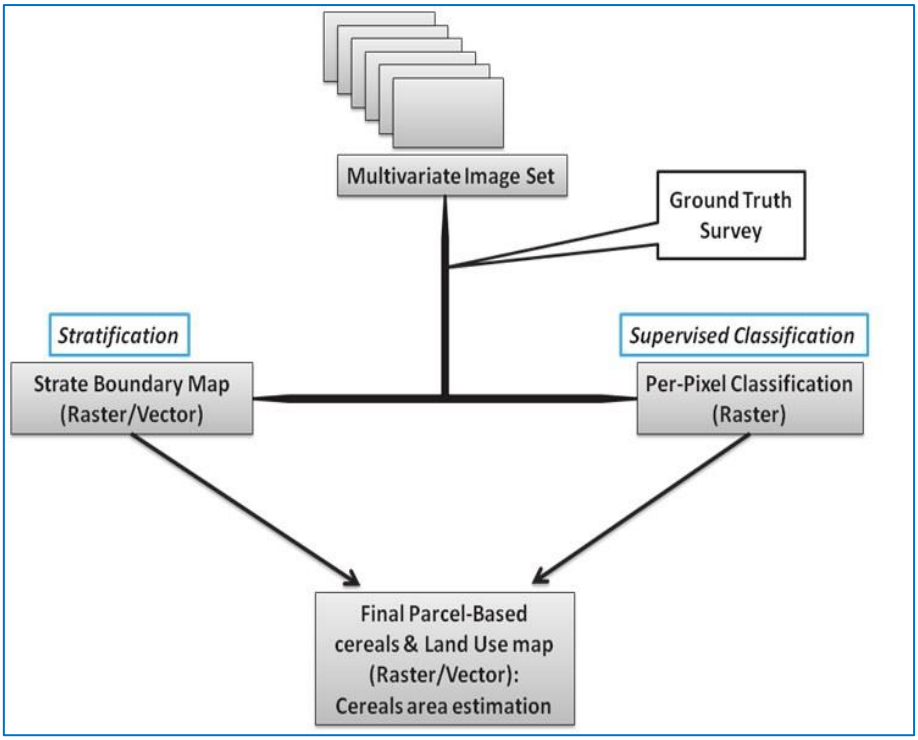

Figure 4: General approach for the classification of Landsat images.

4.2 Accuracy Assessment of Remote Sensing method

Accuracy assessment of cereals area estimates based on remote sensing were carried out using total accuracy and Kappa coefficient (***Table 4***). The accuracy of area estimates is high in all the studied provinces. The methodology based on low resolution images and a detailed crop mask is then able to provide accurate estimates of cereals area in Morocco.

Table 4: Accuracy assessment of cereals area estimates based on remote sensing, for the five studied provinces, during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.

Province	2006-2007		2010-2011		2011-2012		2012-2013	
	Cereals Accuracy	Kappa Coefficient	Cereals Accuracy	Kappa Coefficient	Cereals Accuracy	Kappa Coefficient	Cereals Accuracy	Kappa Coefficient
Benslimane Berrechid Settat	95.24	0.918	93.94	0.908	97.44	0.91	95.83	0.920
Khouribga	94.29	0.886	97.14	0.938	96.00	0.913	96.43	0.919
Meknes	95.56	0.901	95.92	0.910	96.23	0.913	97.78	0.952

5. Conclusion

The objective of this study was to test if cereals area can be estimated in Morocco based on remote sensing classification instead of the classical costly ground survey using area frame sampling (AFS) methodology. The study revealed a high agreement between area estimates derived from ground sampling and based on remote sensing classification. However, remote sensing methodology has still to be extrapolated in order to provide crop acreage information over the entire country.