Crop Monitoring as an

E-agricultural tool in Developing Countries

CROP AREA ESTIMATION

Best approach for crop area estimation in Morocco

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

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

Reviewer(s) : Qinghan Dong

Approver(s) :

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EXECUTIVE SUMMARY

In Morocco, cereals (bread wheat, durum wheat and barley) constitute the basis for food security and are cultivated mostly under rain-fed 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.

Area of the three main cereals in Morocco (soft wheat, durum wheat and barley) was estimated based on supervised classification of 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 crop mask was produced based on aerial photography, topographic maps, ortho-rectified SPOT color images (2.5 meters spatial resolution) acquired in 2008 and, other thematic maps covering all agricultural areas of Morocco. 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. The methodology was used for four contrasted cropping seasons (2006-2007, 2010-2011, 2011-2012 and 2012-2013). Cereal statistics were provided by DSS at provincial level, based on sub-provincial sampling survey, called "Area Frame Sampling" (AFS). The area estimates based on AFS were used as checks. 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 were: 1,193, 574, 478, 448 and 419 in Settat, Benslimane, Berrechid Khouribga and Meknes, respectively.

Results show that the methodology based on low resolution images and a detailed crop mask was able to provide accurate estimates of cereals area 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 rain-fed conditions (in more than 92% of cereal lands). Cereal yield forecasting has already been addressed successfully in Morocco, thanks to previous studies (Balaghi et al., 2008; Balaghi et al., 2012) 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.

Since 1980, cereal datasets were collected from the Direction of Strategy and Statistics of the Ministry of Agriculture (DSS). Statistics on the cereal areas are available at the provincial level (40 provinces) for all the seasons, starting from 1979 till 2012 (**Figure 1**). These datasets are compiled from sub-province sample surveys and released in official documents as provincial averages.

Crop statistics were collected based on Area Frame Sampling (AFS) for the croplands. This method is quite satisfactory for major crops. The Moroccan AFS count for 3,000 segments (SSU) and cover 19 million hectares. Basically, AFS is a complete listing of the entire population of units to be sampled. In AFS methodology, the units to be sampled are areas of land. The methodology consists in 3 main steps: The stratification, the zoning and the sampling (see deliverable D53.1). The statistics derived from this method have permitted to monitor and reflect the agricultural dynamics in Morocco. According to these statistics, the overall cereals area in Morocco is about 4.7 million hectares. The cereals area has known an increase between 1979 and 2012 (**Figure 2**). However, this area is experiencing inter-annual variability (CV = 12%).

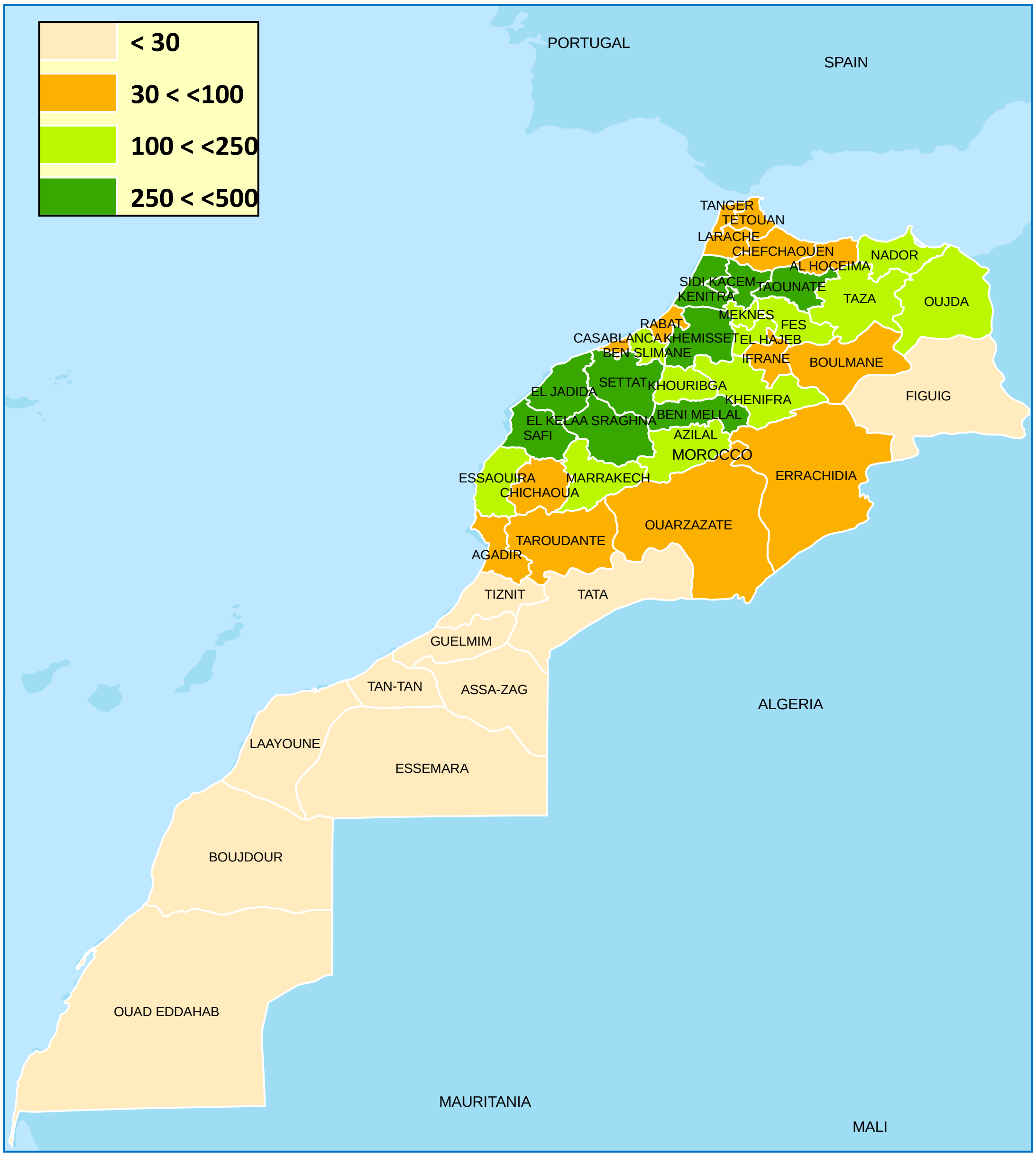

Figure 1 : Map of average production (in Mega tons) of autumn cereals (soft wheat, durum wheat and barley confounded) by province (data series from 1990 to 2010). (Source: Balaghi et al., 2012)

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 (in French, Opération de promotion du blé tendre), launched in 1985-1986 (Jlibene, 2011). This operation was designed to double the cultivated area of soft wheat, from 0.5 million hectares to 1.0 million hectares, using as incentives: the distribution of new improved varieties and fixed prices for harvested grain for producers, and fixed marketing margins for industrials (Ait El Mekki, 2006). The area of soft wheat which had stagnated at around half a million hectares for over thirty years, until the early 1980s, has been doubled in 1986, and multiplied by four, ten years later (Balaghi et al., 2012). The area stabilized then at around two million hectares, occupying more than a fifth (1.9 million hectares, from 1998 to 2011) of the agricultural area of the country (8.7 million hectares). Over the period 1998-2011, the area of soft wheat has increased at an average rate of 34,900 hectares/season, accounting for 88% of total cereal area increase. The area of durum wheat and barley declined at a rate of 11,600 and 13,800 hectares/season, respectively (**Figure 2**).

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 a new sampling approach based on official crop statistics and remote sensing for cereals area estimation in Morocco.

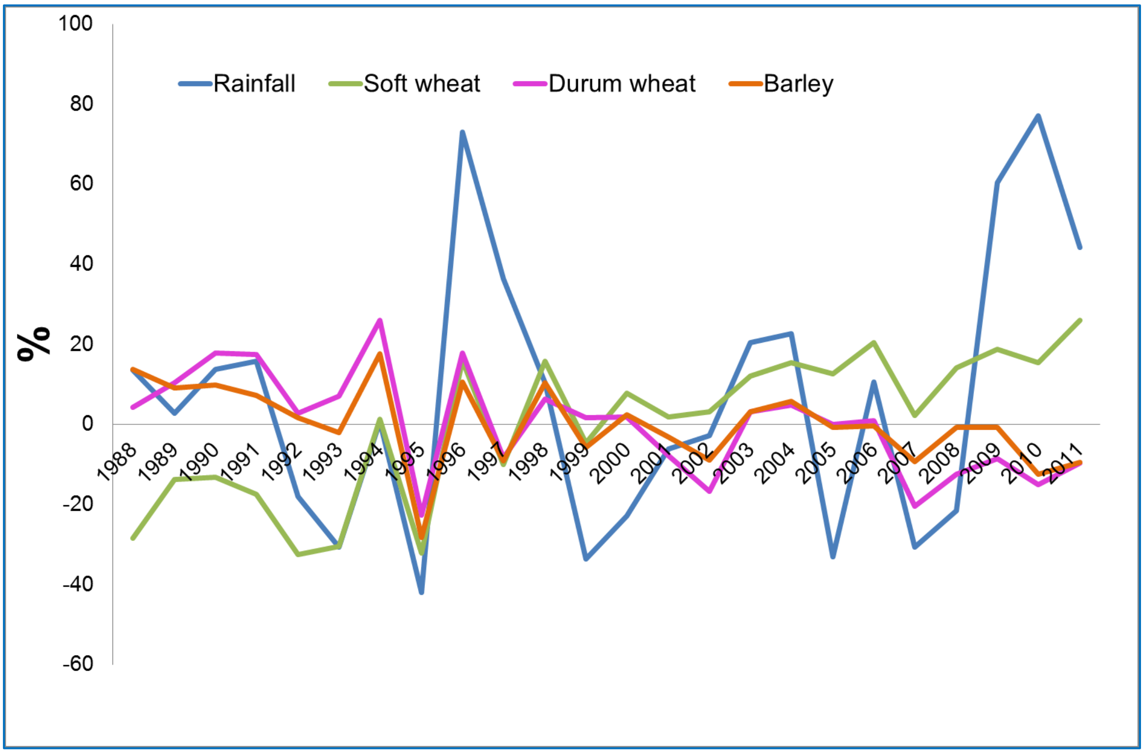

Figure 2: Deviation (%) from mean value of cumulated rainfall over September to May period, and of main cereal area (soft wheat, durum wheat and barley), at the country level (data from 1988 to 2011) (Source: Balaghi et al., 2012).

Selected tests sites were two main cereal growing regions of Morocco: Chaouia-Ouardigha region and Meknes province. Estimates obtained from field surveys and Landsat image classification were compared. This comparison enables the evaluation of both field survey and image interpretation results. On the other hand, sources of errors can be identified through this comparison. To improve crop type acreage by combining the estimates obtained by field survey with the estimates produced by image classification. Combining the two sets of data may reduce the field sampling error on the one hand and reduce the image classification errors on the other hand. As this study is the first remote sensing study of cereal acreage estimation in Morocco, results of the study may help in improving the performance and the methodology of future remote sensing studies.

2. Study areas in Morocco

Two main growing cereals areas were selected for this study, Chaouia-Ouardigha region which is located in a semi-arid zone (average rainfall = 350 mm), and Meknes province which located in a sub-humid zone (average rainfall = 450 mm) (Figure 3).

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 (33° 0′ 0″ N and 7° 37′ 0″ W), covering an area of approximately 16,510 km^2 (Figure 3). All 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 rain-fed agriculture (69%), forests (12%) and rangelands (11%). Most of the lands of the selected provinces are covered by rain-fed 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%).

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 3). 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 rain-fed (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 inter-annual 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.

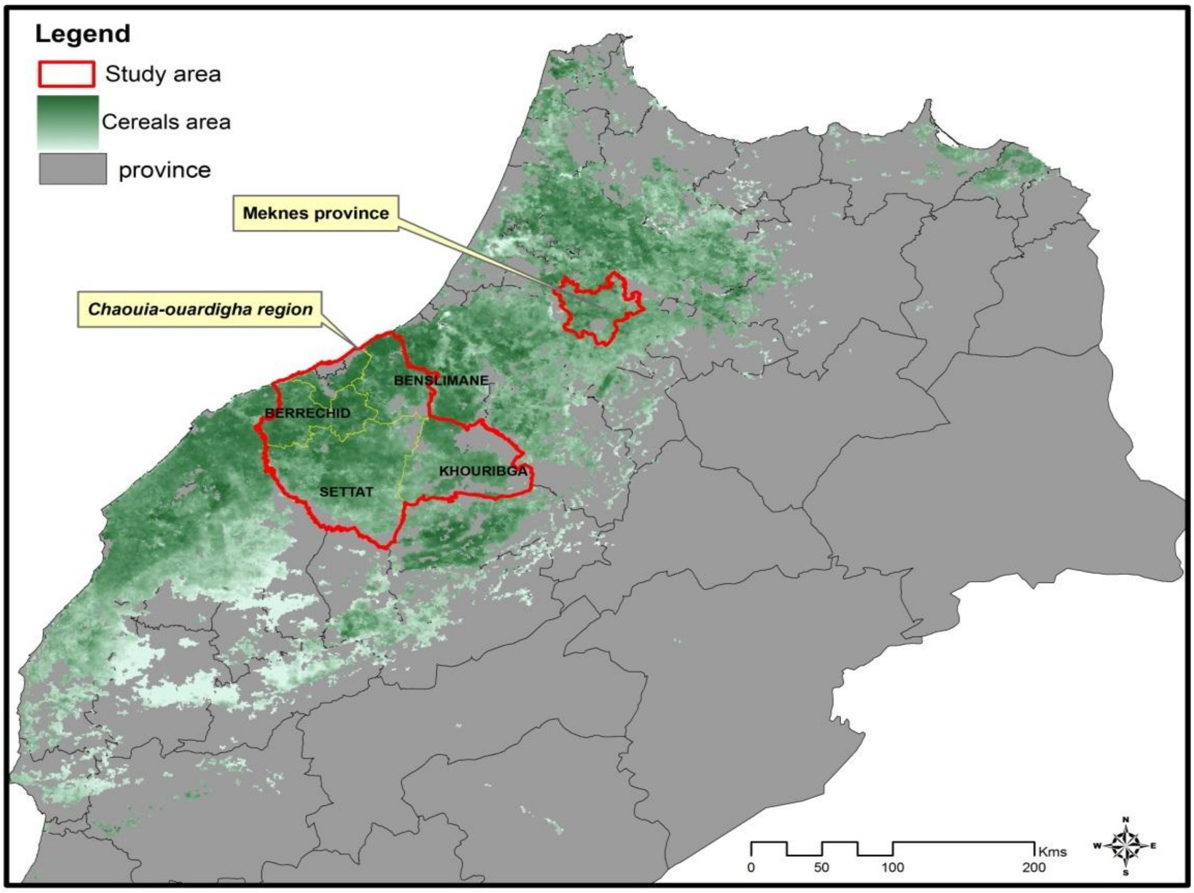

Figure 3: The two selected test areas (boundaries in red), for area assessment based on Remote Sensing. The two areas cover a significant part of the agricultural lands of Morocco (in green). Agricultural lands were extracted from Global Land Cover 2000 map (GLC2000 version 5.0, Mayaux et al., 2004).

3. Data sets and Methods

3.1. Ancillary

Main data collected include: (1) official cereal statistics (area and yield) by season from 1978-1979 till 2011-2012, and by province; (2) vector map with the detailed boundaries of the province administrative boundaries, and the road network data, etc. Other GIS data collected are: the Digital Elevation Model from the Shuttle Radar Topography Mission (30 meters spatial resolution), rainfall data by province and by season from 1987-1988 to 2011-2012, and the land cover maps GLC2000 and Globcover (Tchuente *et al*., 2010; Neumann *et al*., 2011). The most recent stratification of the study area provided by DDS (deliverable 53.1) were used to pre-define the classification legend.

3.2. Classification Legend

At the level of the image classification, all attempts were made to distinguish the cereals class from rainfed cropland areas. However, some minor units were merged into cereals class, as legumes (areas < 3%), but all the main classes with area above 3% and probably less) were kept apart. The classification legend typically comprises the following terrain classes: Cereals; Fallow; Irrigated Cropland; fruits trees; Forests; Rangelands; Urban and rural zones and Water bodies.

3.3. 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.

3.3.1 The stratification

The distribution of crops can vary considerably across a province in Morocco. 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 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).

3.3.2 The zoning

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. Figure 4 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 (Rain-fed agricultural lands) in the Chaouia-Ouardigha region.

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

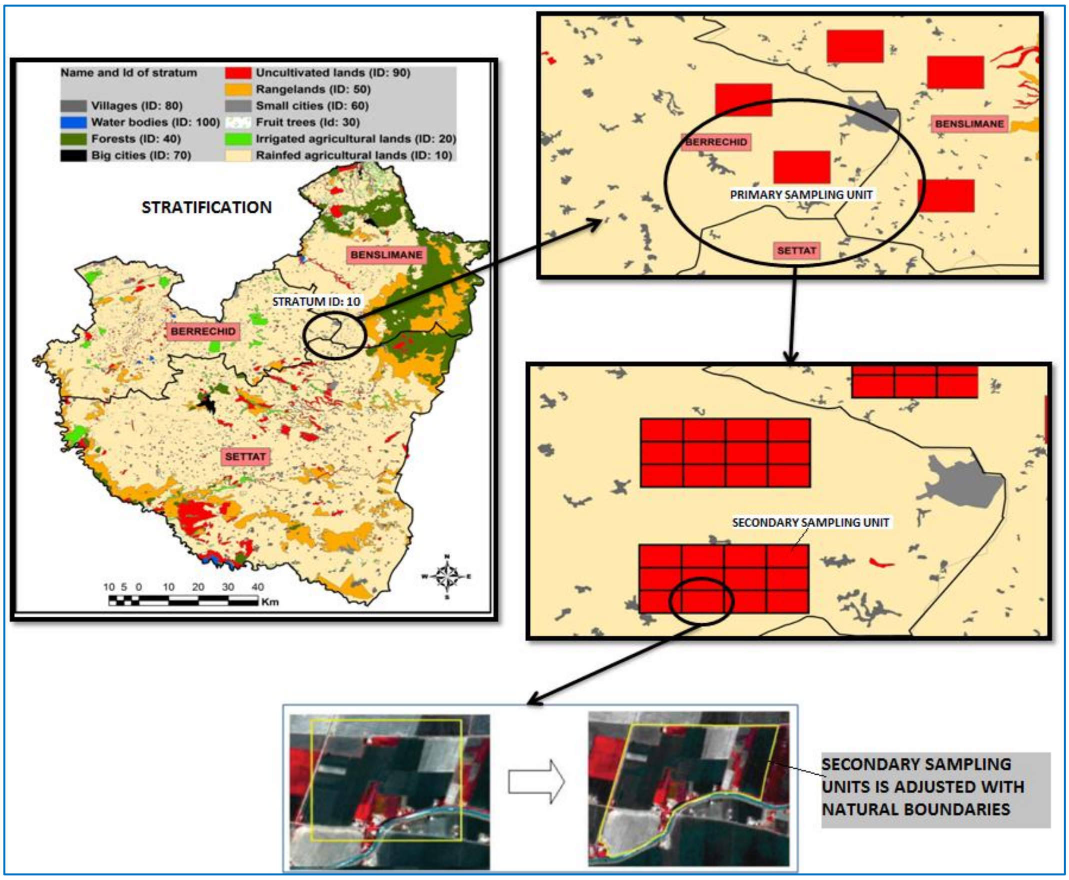

Figure 4: Example of the scheme of area frame sampling, in the Chaouia-Ouardigha region.

3.4. Cereals 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* = Σws.Ys = Σ (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 (h): area of stratum h;
- 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 (h) divided by the total area observed in the sample;

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

3.4.1. Image acquisition and pre-processing

TERRA-MODIS and rainfall data

The MODIS Normalized Difference Vegetation Index (NDVI) 16-days product time series were used to study the vegetation profile so that and to determine picks of vegetation in the studied regions (http://www.pecad.fas.usda.gov/cropexplorer/modis_ndvi/). NDVI is based on the near infra-red channel (NIR), where the vegetation has an important reflectance, and the red channel (R), where the vegetation has a low reflectance. The formula for determining NDVI is: NDVI = (NIR -R)/ (NIR + R) (Rouse et al., 1973; Tucker, 1979).
The time series starts in 2000 and ends in 2013. The MODIS data were re-projected from the Sinusoidal projection to Moroccan Lambert conformal conic projection. The mask of rainfed croplands (strata 10) was provided by DSS. It was produced based on the classification of

high resolution SPOT-5 images and re-sampled to 250 meters/pixel. Thus, time series of NDVI belonging to rainfed cropland area were treated and analyzed, for the time period of 2000 - 2012.

Also, monthly rainfall data for the studied regions were taken from CGMS-MAROC (http://www.cgms-maroc.ma/) which is the Web viewer developed in the framework of the E-AGRI project. Daily rainfall data were collected for four seasons (2006-2007, 2010-2011, 2011-2012 and 2012-2013), in order to verify NDVI profiles.

Finally, statistical analyses were performed using one-way ANOVA and the mean comparisons were made using the least significant difference (LSD) method with $p<0.05$.

Landsat TM5 and ETM+7 scenes

The main data used in this study 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. 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 5) of 2007, 2011, 2012 and 2013 years, taken on several periods during years were used to cover the different study areas (Table 2). 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 landcover 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.

Table 2: Name and acquisition date of the remote sensing data for the studied provinces.

Study area	Sensor	Path/Row	Acquisition Data
Settat, Berrechid, Benslimane	TM 5	202/037	01/08/2010
	TM 5	202/037	08/01/2011
	TM 5	202/037	09/02/2011
	TM 5	202/037	25/02/2011
	ETM+7	202/037	21/03/2011
	TM 5	202/037	14/04/2011
	ETM+7	202/037	15/10/2011
	ETM+7	202/037	04/02/2012
	ETM+7	202/037	20/02/2012
	ETM+7	202/037	26/03/2013
Khouribga	TM 5	201/037	11/03/2007
	TM 5	201/037	22/03/2011
	ETM+7	201/037	13/02/2012
	ETM+7	201/037	15/02/2013
Meknes	TM5	201/036	28/07/2011
	ETM+7	201/036	13/02/2012
	ETM+7	201/036	16/03/2012
	ETM+7	201/036	17/04/2012
	ETM+7	201/036	15/02/2013

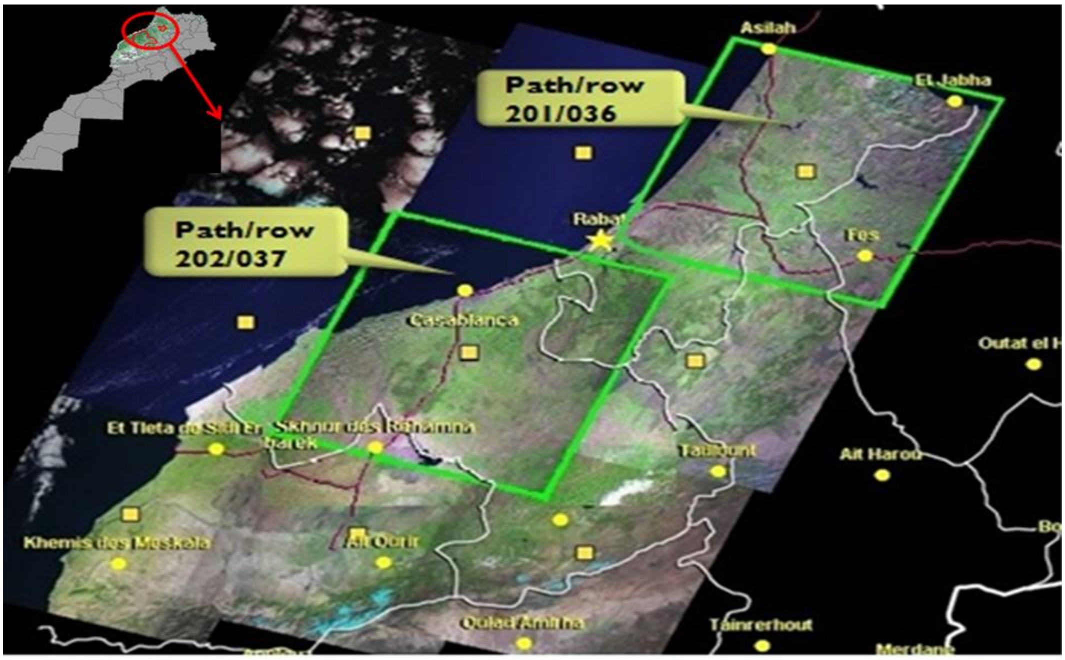

Figure 5: Example of Landsat7-ETM scenes, registered for the two "frames" covering the "study areas": the 202/037 scene covers Chaouia-Ouardigha region and the 201/036 covers the Meknes provinces. Source: GLOVIS website.

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 reserved 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 (see deliverable 5.31). Thus, the general approach for the classification of Landsat images is illustrated in Figure 6.

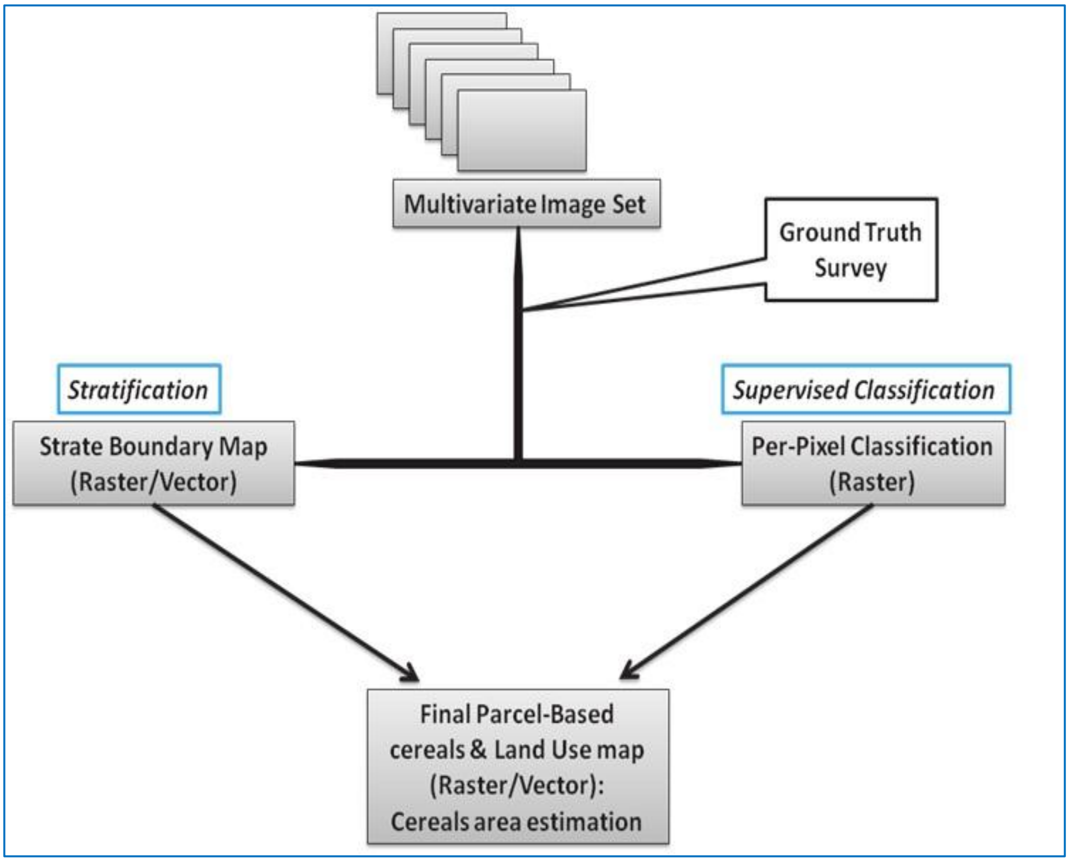

Figure 6 : General approach for the classification of Landsat images.

3.5. 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 staff members of 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 were: 1,193, 574, 478, 448 and 419 in Settat, Benslimane, Berrechid Khouribga and Meknes, respectively.
Enumerators from DSS and the farmers concerned by the survey carried out annotation work of the field numbers, location, land cover type in the sample units and collection of information about each plot (Figure 7 and Figure 8). For each segment a set of documents

are prepared comprising a color plot at scale 1:5000 of the most recent high resolution, orthorectified satellite image (Figure 9).

The segment boundaries are identified and adjusted where necessary on the cartographic support that contains all the necessary and relevant benchmarks (tracks, roads, streams, wells, habitats etc...).

Figure 7: Identification and Delimitation of plots on the field.

Figure 8: Identification and Limit of stratums

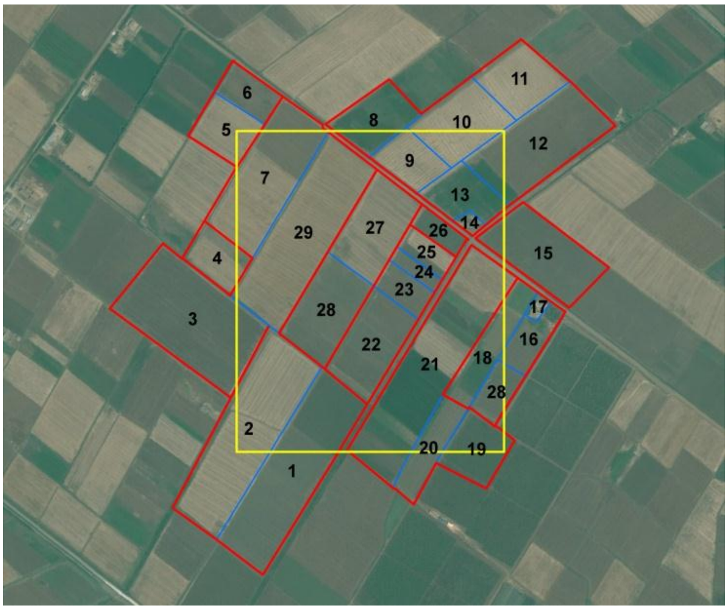

Figure 9: Delimitation of the lots and fields on the spot5 Images (2.5 m)

3.6. Accuracy Assessment (Validation)

SSU samples were used to test crop classification accuracies. Hence, half of SSU data for cereal class were used to validate cereals class produced by supervised classification of Landsat TM5/ETM7 images. The accuracy of the classification was determined by comparing the SSU set with the classification results and to generate cereals accuracy percentage, and the Kappa Coefficient.

4. Results and Analysis

4.1. Temporal patterns in NDVI variability

The biweekly patterns in NDVI variability over of each of three studied provinces: Settat, Khouribga and Meknes for the period 2000 to 2013 are shown as examples in Figure 10. These curves follow similar temporal variations (i.e., sinusoidal curve), but differ significantly in amplitude. On a seasonal scale, these curves exhibit major peaks and valleys. These features coincide with the wet and dry seasons with peaks corresponding to the rainy season and the valleys corresponding to the dry season. The peaks appear during February and March while low valleys occur during July and August.

These marked seasonal oscillations correspond to the vegetation state during the cropping season. On an annual scale, NDVI variations are modulated by wet and dry seasons. The inter-annual oscillation corresponds to the vegetation state during the growing season. The analysis of variance showed a significant difference in NDVI values between the various studied seasons. For instance, the well-known 1999-2000 and 2006-2007 dry seasons, and 2012-2013 and 2002-2003 wet seasons are clearly seen. There is also a significant difference in vegetation growth between the biweekly NDVI curves for the studied seasons (2006-2007, 2010-2011, 2011-2012 and 2012-2013) and the between the studied regions. Note that NDVI during the period February–March is higher, which is an indication of the abundance of vegetation during this period. It is suggested that the contrasting variations in NDVI values among the curves reflect the effect of rainfall variability on vegetation dynamics.

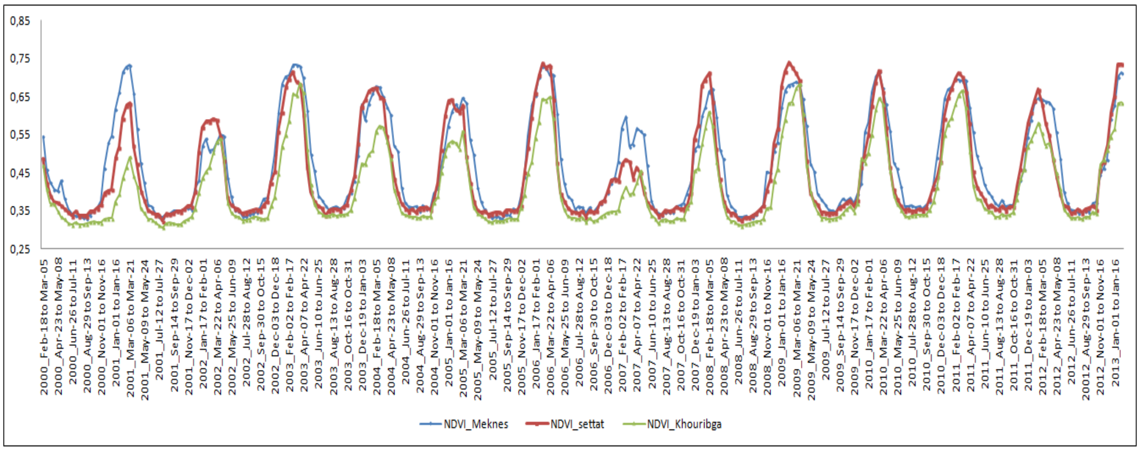

Figure 10: Biweekly NDVI time series averaged over tree zones (Settat, Kouribga and Meknes) for the period 2000–2013. The NDVI curves correspond to the three provinces.

4.2. Rainfall profile during study periods

Figure 11 shows cumulative rainfall from September till May for seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013, for three provinces of Settat, Khouribga and Meknes. Analysis of cumulative rainfall reveals that wet seasons were 2010-2011 and 2011-2013, whereas dry seasons were 2006-2007 and 2011-2012. During season of 2011-2012, the vegetation was normal despite low rainfall, due to low recorded temperatures which mitigated drought during this season.

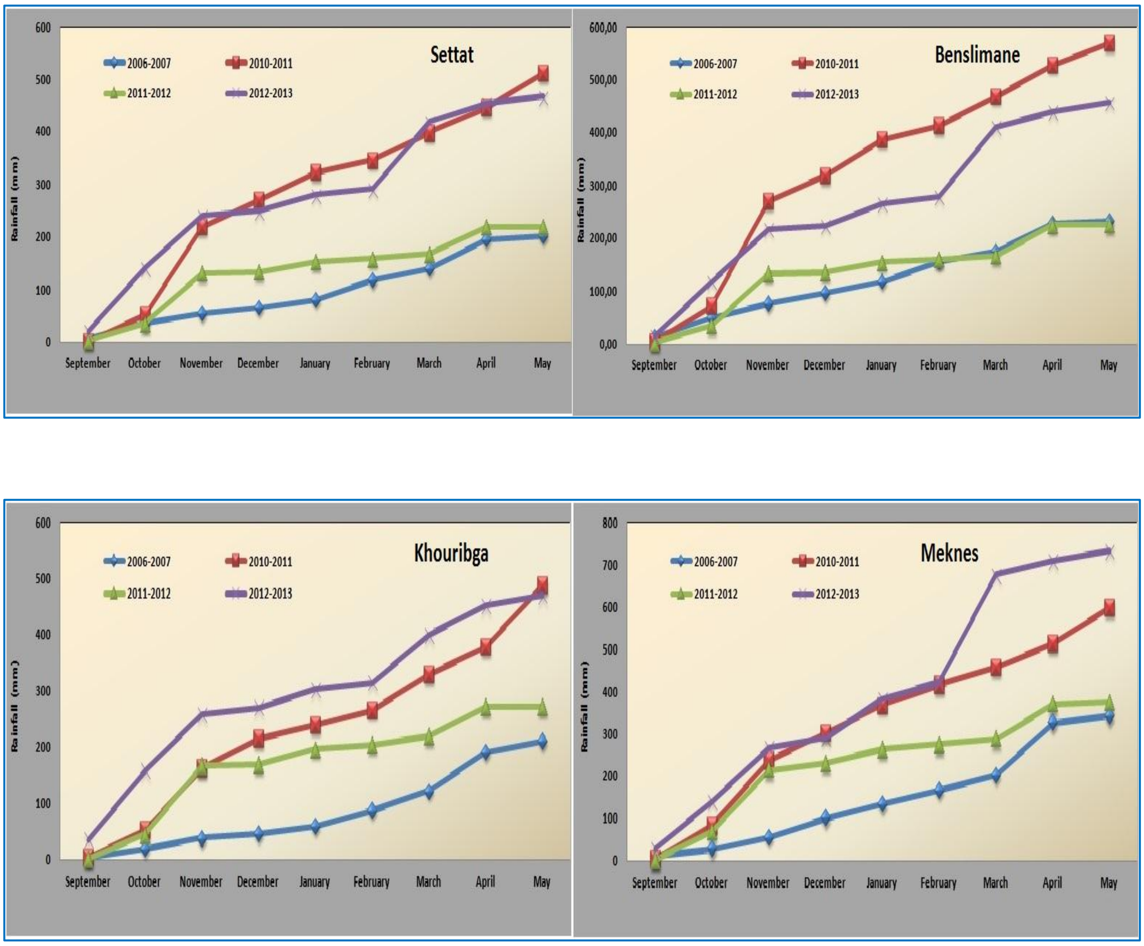

Figure 11: Cumulative rainfall totals from September to May of 2007, 2011, 2012 and 2013 in Settat, Benslimane, Khouribga and Meknes provinces

4.3. Estimates based on the Field Survey: Area frame sampling (AFS)

Cereals area estimation from ASF during seasons of 2010-2011, 2011-2012 and 2012-2013 in the five studied provinces are shown in the Table 3, Table 4 and Table 5. 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 acreage in all provinces during season of 2010-2011, 2011-2012 and 2012-2013. Results further indicate that during 2012-2013, the cereals area was important in Khouribga, Settat and Meknes provinces. 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 2010-2011; 2011-2012 and 2012-2013 are the followings:

- Berrechid: 180,434; 146,644, and 160,053 hectares;
- Settat: 355,969; 362,177 and 382,248 hectares ;
- Berrechid: 67,409; 76,811 and 72,086 hectares ;
- Khouribga: 180,264; 185,443 and 203,311 hectares ;

Concerning Meknes province, area estimates are: 55,454 and 57,555 hectares for season of 2011-2012 and 2012-2013.

Table 3: Area estimates (Hectare) for cereals (soft wheat, durum wheat and barley) in the studied provinces during season of 2010-2011.

2011	Y (h)	Y_T	CE	Y_{barley}	$Y_{durum\ wheat}$	$Y_{soft\ wheat}$	Barley	Durum wheat	Soft wheat	All cereals
BENSLIMANE	133570	1405	95	150	118	440	**14292**	**11242**	**41876**	**67409**
BERRECHID	222120	1622	137	135	451	731	**18483**	**61818**	**100133**	**180434**
KHOURIBGA	270288	1994	136	605	215	510	**82048**	**29128**	**69087**	**180264**
SETTAT	498917	3021	165	727	669	760	**120038**	**110388**	**125543**	**355969**

Y (h): area of stratum h; Y_T: total area observed in the sample; Y_{cer}: Surface observed on cereals in the sample; CE: Extrapolation coefficient.

Table 4: Area estimates (Hectare) for cereals (soft wheat, durum wheat and barley) in the studied provinces during season of 2011-2012.

2012	Y (h)	Y_T	CE	Y_{barley}	$Y_{durum\ wheat}$	$Y_{soft\ wheat}$	Barley	Durum wheat	Soft wheat	All 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 (h): area of stratum h; Y_T: total area observed in the sample; Y_{cer}: Surface observed on cereals in the sample; CE: Extrapolation coefficient.

Table 5: Area estimates (Hectare) for cereals (soft wheat, durum wheat and barley) in the studied provinces during season of 2012-2013.

2013	Y (h)	Y_T	CE	Y_{barley}	$Y_{durum\ wheat}$	$Y_{soft\ wheat}$	Barley	Durum wheat	Soft wheat	All cereals
BENSLIMANE	133570	2482	54	288	15504	873	**46962**	**179**	**9620**	**72086**
BERRECHID	222120	2166	103	636	65197	644	**66060**	**281**	**28797**	**160053**
KHOURIBGA	270288	2247	120	265	31829	350	**42137**	**1075**	**129345**	**203311**
SETTAT	498917	3896	128	1285	164632	783	**100268**	**916**	**117348**	**382248**
MEKNES	104086	1109	94	10	978	564	**52924**	**39**	**3653**	**57555**

Y (h): area of stratum h; Y_T: total area observed in the sample; Y_{cer}: Surface observed on cereals in the sample; CE: Extrapolation coefficient.

4.4. Area estimates based on Remote Sensing

Supervised classification from remote sensing was performed on strata 10 (rainfed croplands; crop mask provided by DSS) in the five provinces (Settat, Khouribga, Benslimane, Berrechid and Meknes) and during four seasons (2006-2007, 2010-2011, 2011-2012 and 2012-2013).

Cropland classification for the seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013 is shown in Figure 12, Figure 13 and Figure 14, for provinces of Settat, Benslimane, Berrechid, Khouribga and Meknes, respectively. Landcover was classified into 9 classes as reported in deliverable 5.31. The classes correspond to cereals, fallow, Forest, rangeland, irrigated agricultural lands, water bodies, urban and rural zones and others.

Spatially, cereals are located mostly in rain-fed cropland. It was not possible to discriminate between cereals and legumes from supervised classifications. However, legumes crop rarely exceeds 3% of the surface of studied provinces, according to official statistics.

Also, it is important to mention here that the intent of the study was limited to spatial identification of the all cereals confounded and fallow.

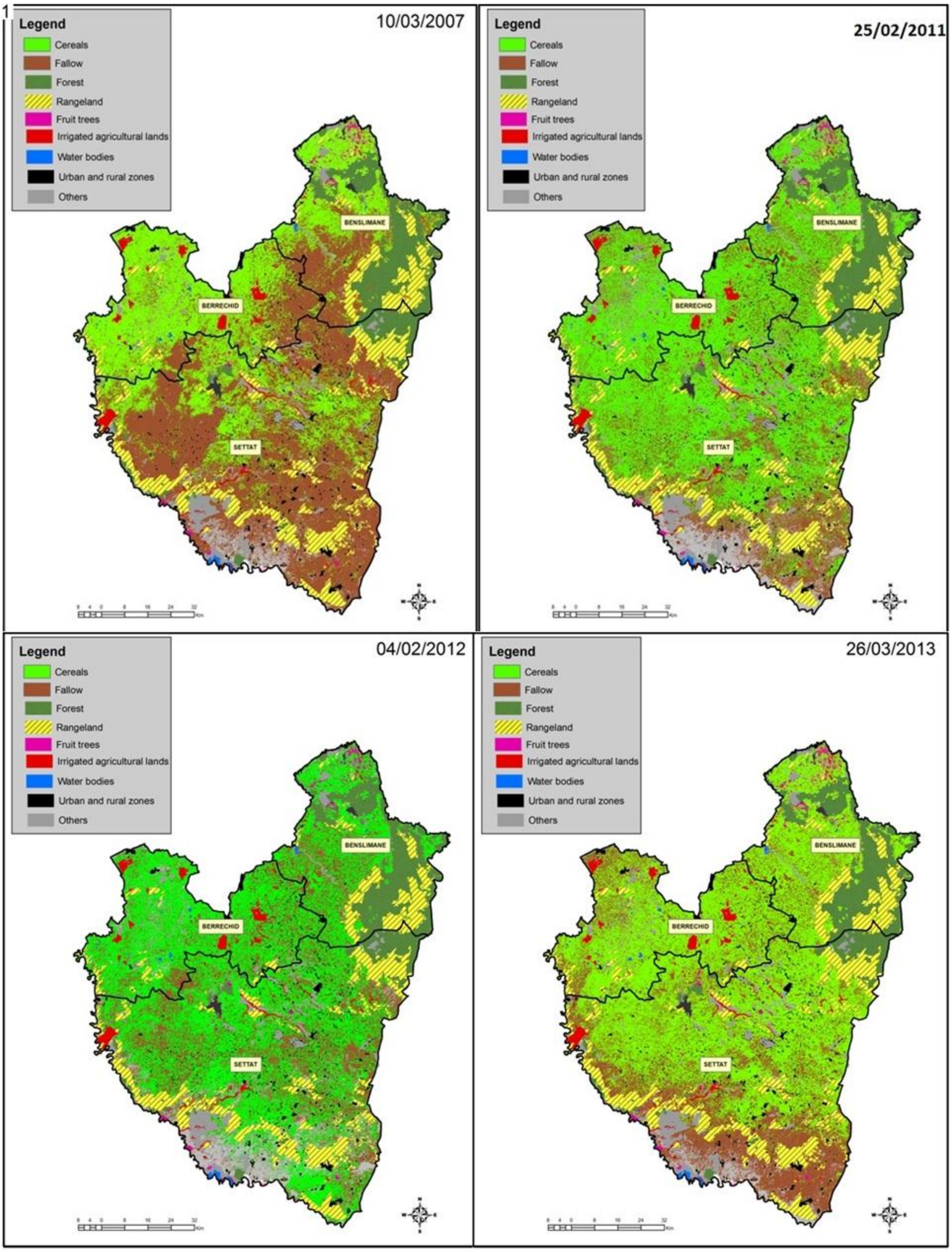

Figure 12: Land cover map of Settat, Berrechid and Benslimane provinces showing the spatial distribution of cereals (green color) during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.

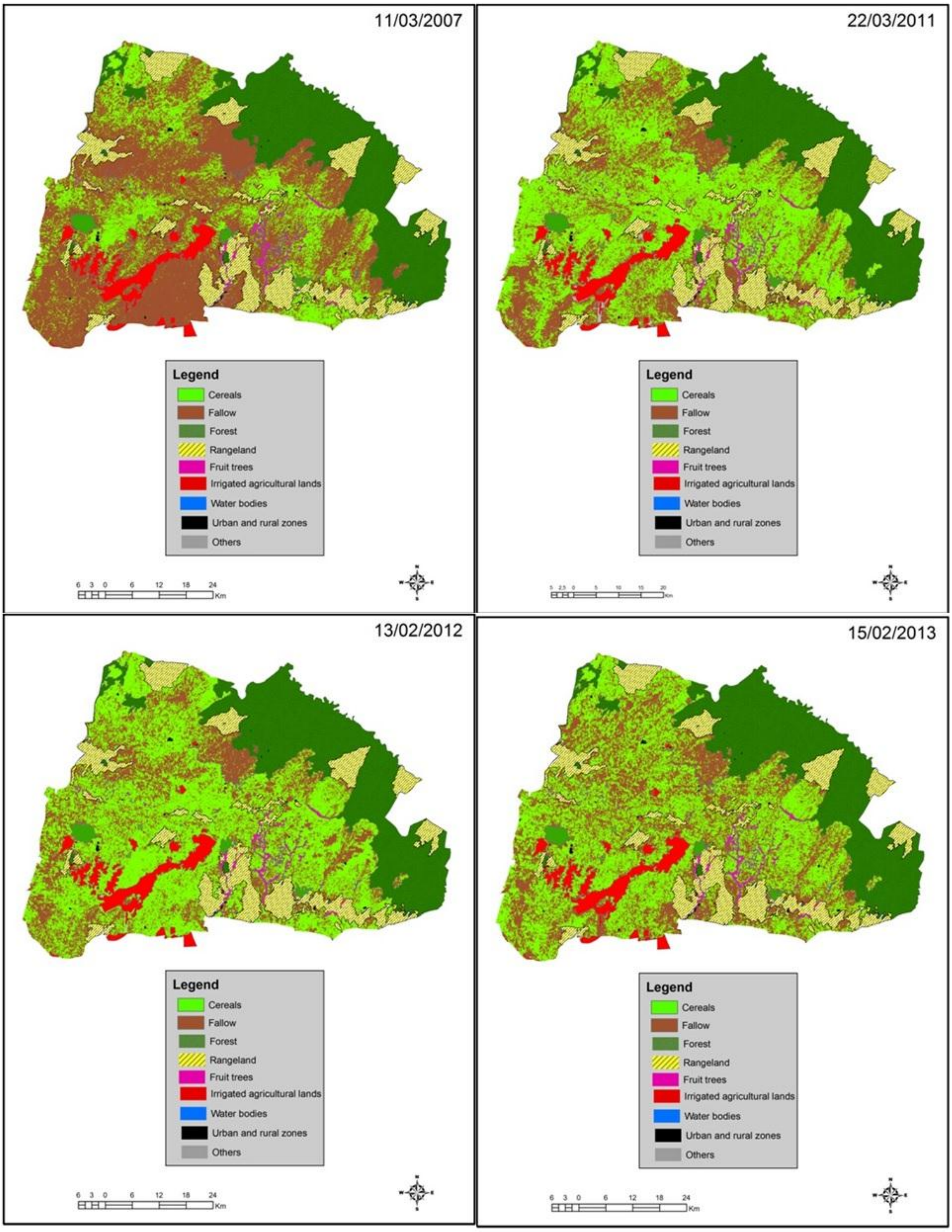

Figure 13: Land cover map of Khouribga province showing the spatial distribution of cereals (green color) during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.

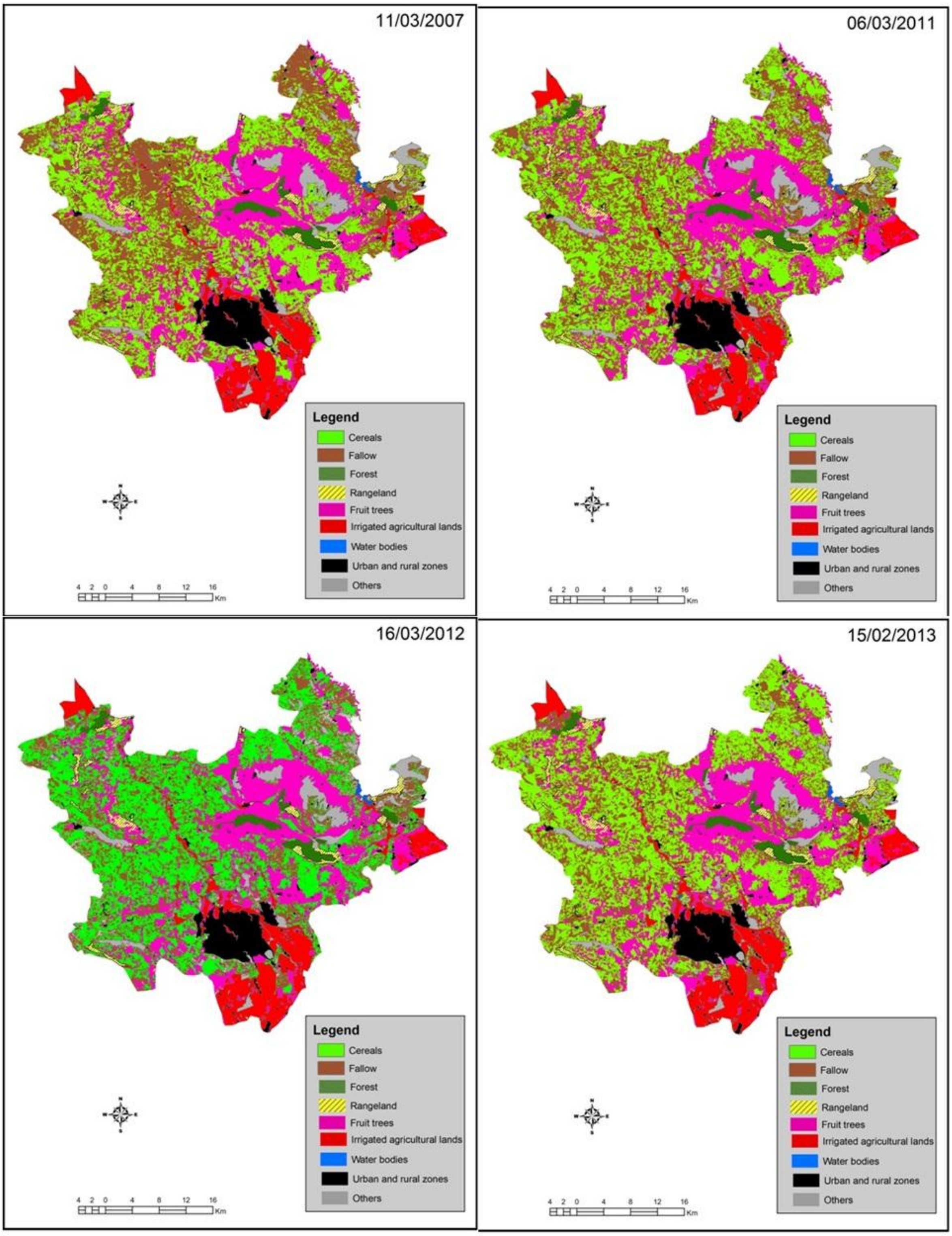

Figure 14: Land cover map of Meknes province showing the spatial distribution of cereals (green color) during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.

According to the Landsat TM/ETM7 images classification, cereals area estimates are the followings (Figure 15):

- In Benslimane: 72,846; 89,138; 85,413 and 106,973 hectares during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013, respectively (55, 67, 64, and 80%, respectively) ;
- In Berrechid: 161,174; 156,632; 145,777 and 163,719 hectares during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013, respectively (73, 71, 66; and 74%, respectively) ;
- In Settat: 120,933; 315,810; 265,331 and 284,224 hectares during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013, respectively (24, 63, 53; and 57%, respectively)
- In Khouribga: 85,000; 164,350; 176,780 and 153,770 hectares during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013, respectively (31, 61, 65 and 57%, respectively).
- In Meknes: 60,570; 58,630; 63,922 and 67,930 hectares during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013, respectively (58, 56, 61 and 65% respectively).

It should be noted that cereals area varies from one year to another according to rainfall conditions. For instance, the total cereals area was low during season of 2006-2007 due to drought, corresponding to 24, 31, 55 and 58% of the total area of strata 10, in Settat, Khouribga, Benslimane and Meknes, respectively. In contrast, during cropping season of 2011-2012 and 2012-2013 cereals area was important in Settat for example due to high precipitations during this season.

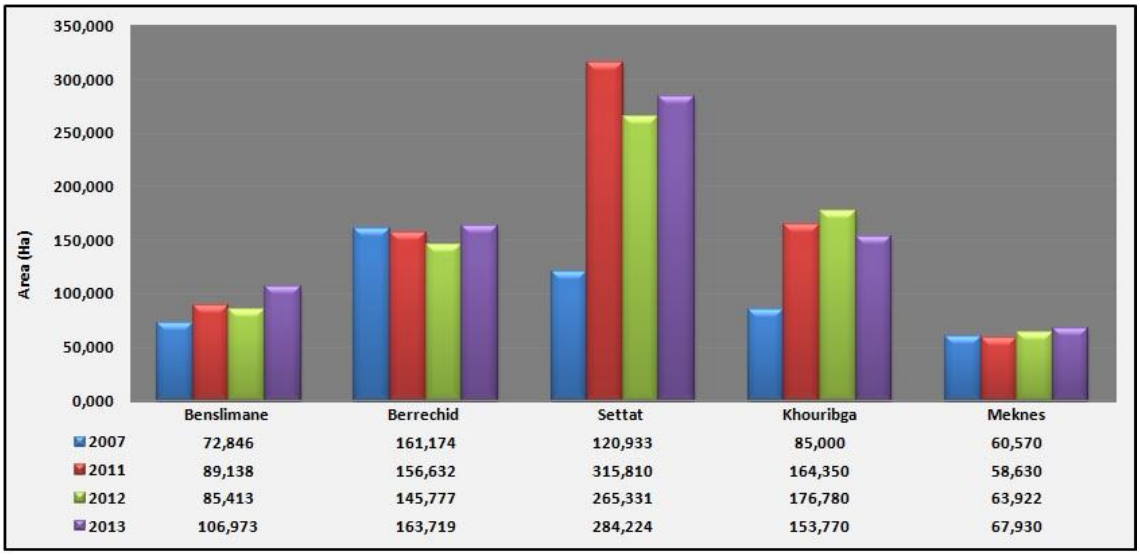

Figure 15: Area estimates based on remote sensing classification, for the three cereals (soft wheat, durum wheat and barley) in the studied provinces (Settat, Benslimane, Berrechid, Khouribga and Meknes), during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.

4.5. Accuracy Assessment of Remote Sensing classification

Area estimates based on remote sensing were validated using AFS estimates (Table 6). The accuracy of area estimates is high in all the studied provinces whatever the season is. 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 6: 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 correspondence between area estimates derived from ground sampling and remote sensing classification. However, remote sensing methodology still has to be extrapolated to provide crop acreage information over the entire country.