The Use of Satellite Imagery to Detect Agricultural Field Encroachment on the Communal Rangelands of the Aïn Béni Mathar Commune, NE Morocco.

N. J. W. Thomas [a]*, M. Bounejmate [b]

a ESRI Inc, 380 New York Street, Redlands, CA 92373 – nthomas@esri.com
b International Centre for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria

Abstract - The encroachment of agricultural practices into traditional rangeland areas of north-eastern Morocco is considered by some to have negative impacts in both the agro-pastoral communities that utilise these ranges and the surrounding physical environment. Indicating the extent and location of such land use changes provides resource managers with valuable information on which more sustainable development and policy decisions can be based. As part of ongoing research to highlight the mechanism by which participatory rangeland management and restoration can be achieved, satellite imagery from 1988 and 2000 was analysed to indicate to what extent agricultural encroachment had taken place within the ranges close to the Aïn Béni Mathar commune. Results indicated that the degree of encroachment was not as severe as first indicated by participatory farmer surveys however the condition of communal rangelands was seen to have significantly deteriorated between the dates of the study.

Keywords: Land use; Change Detection; Agro-Pastoralism; Rangeland; Satellite Imagery

1. INTRODUCTION

The development of new cropland areas into the traditional rangelands of north-eastern Morocco impacts both the agro-pastoral communities that utilise these ranges and the physical environment. Indicating the extent and location of such land use changes provides resource managers with information used to create more sustainable development policies. Information related to landscape dynamics over large areas frequently uses satellite imagery due to its greater geographical extent and cost effectiveness (Tueller, 1982). As part of ongoing research into the mechanisms that participatory rangeland management and restoration can be achieved, satellite imagery between 1988 and 2000 was analysed to indicate the degree of cropland encroachment that had taken place within the communal ranges of Aïn Béni Mathar.

2. THE STUDY SITE

Selected because of its mixed rangeland and agricultural farming system, the Aïn Béni Mathar commune covers and area of 1462km^2 in the north-eastern highlands of Morocco. The commune is divided amongst twenty-one villages with an additional zone being considered as irrigated and as such collectively managed. Farmer surveys conducted by the local directorate of agricultural, Institut Nacional de Recherche Agronomique (INRA-Oujda), show that cropped areas increase on average between 300 and 400 ha annually, and that a total of 25,760ha (18%) of the whole commune is now considered to have been cultivated (INRA-Oujda, 2000). Degradation of the rangelands is locally considered as a threat to the traditional livelihood of the 7,300 inhabitants and the exploitation of newly developed agricultural lands has been proposed as a likely source of future conflict.

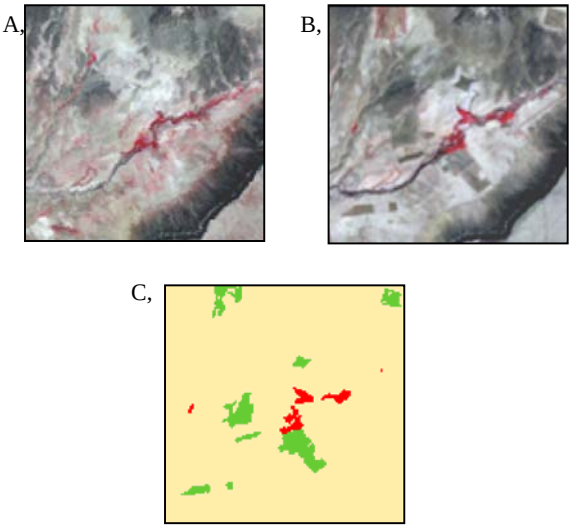
3. MATERIALS AND METHODS

The imagery used needed to be of sufficient spectral and spatial resolution to identify any new fields which according to the farmer interviews conducted by INRA-Oujda were on average 100x200 metres in size. In order to minimize potential confusion in the land use classification caused by seasonal variations in vegetative biomass, the images were acquired for the same month. Images used were a Landsat Thematic Mapper (TM) from March 1988 and a Landsat Enhanced Thematic Mapper (ETM) image from March 2000. The season which the images represented, spring, is the period of the year when differences between agricultural fields and natural rangeland vegetation are greatest. The imagery was used to separate and quantify the land cover of the region into agricultural fields and rangeland vegetation. Once processing had been completed, any changes evident between the two dates were calculated. Geometric and radiometric correction of the images was carried out to facilitate the quantification of areas and permit the overlay of the two images. The ability to precisely overlay the images was vital if comparative areal assessment was to be achieved. The positional error calculated between the two images was found to be on average, ± 0.452 pixels, representing 12.65 metres on the ground. Initial analysis of the images showed that standard image classification routines, based solely on spectral statistics were not sufficient to identify all of the fields apparent through manual image interpretation. Automated classification and identification of irrigated fields was successful. Non-irrigated fields, rainfed or fallow/abandoned, were not as easily identified due to their spectral signatures resembling the natural rangeland vegetation. Irrigated fields produce crops with a higher Leaf Area Index (LAI) to soil ratio than rainfed crops in the region. The result is that means of interpretation methods relying solely on spectral statistics will confuse such non-irrigated fields with areas of sparse

natural vegetation as found in the study area. The image analyst is able to manually distinguish the two cover types by taking into consideration the shape of a particular landscape unit. A two tiered interpretation method was therefore commissioned that would both locate irrigated fields in the two images and identify all other fields visible only in the 2000 image.

The Normalized Difference Vegetation Index (NDVI) was calculated for both years. The index highlights areas that have high reflectance in the near infrared and normalises the resultant image between 0 to 1 (Lillesand and Kiefer, 1994). Verdant vegetation has a high value whereas bare soils, water and areas of sparse vegetation have lower values. Interpretation of the NDVI results for the two years showed that the irrigated fields could be confidently identified. Further information regarding the condition of natural rangeland could also be obtained. As mentioned previously, both images came from the month of March. However, NDVI values calculated for the known natural range cover from the 1988 image were consistently higher than those from 2000 indicating that range biomass had previously been greater. Using data collected from the field in the spring of 1999, the NDVI results from both years were 'level sliced' using the same thresholds to produce a broader classification of land use. The thresholds were selected to reduce any reclassification errors of omission for the irrigated fields. The differences in range biomass indicated by the NDVI values obtained between 1988 and 2000, mean that the 1988 image produced the following land use classes, irrigated fields, medium range and other land use. For 2000, values classified as medium range in 1988 did not exist and so only two classes, irrigated fields and other land use, could be extracted. The 'other' class can be considered poor range. To identify non-irrigated fields created between 1988 and 2000, visual comparison of the two images followed by manual vectorisation of the boundaries was conducted. Using a combination of the two techniques (Figure 1), the total degree of agricultural expansion between 1988 and 2000 was obtained by summing the areas identified as irrigated and non-irrigated fields.

Figure 1 – A. Subset of Aïn Béni Mathar showing the situation as observed in the 1988 image, B, the newly developed fields by 2000, and C the resultant land cover classification for the year 2000 (red – irrigated fields, green – new fields, beige – poor range).



4. RESULTS

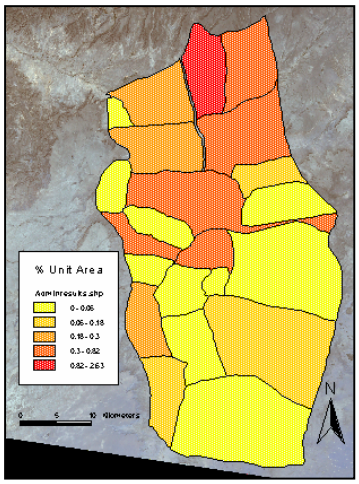
The NDVI image provided an indication not only of the irrigated fields but also of the changes in the degree of surrounding rangeland vegetation coverage. Whilst in 1988, areas exist that can be considered rangelands of moderate standard, they are not present in 2000. This indicates that the overall state of non-cultivated vegetation cover has deteriorated between the two dates. The results of the land use characterization by pasture territory are shown in Table 1.

TABLE 1 – LANDUSE BY NAMED PASTURE AND YEAR (hectares)

	1988			2000			
Pasture Territory	Irrigated Fields	Medium Rangelands	Poor Rangelands	Irrigated Fields	New Fields	Poor Rangelands	Territory Area (2000)
Batmat Ikiad	0.7	92.9	1003.1	1.6	0.00	1098.6	1100.2
Hlasat Ibal	17.2	590.4	5917.2	16.15	18.9	6495.3	6530.3
Hassi Byad	20.5	1334.7	4532	41.1	155.1	5693.4	5889.6
Mechraa Harcha	36.9	1350.6	5624.8	38.7	47.8	6926.8	7013.4
Ouzayane	15.4	1826.3	7988.6	26	79.03	9726.7	9831.7
Sehb El Harmel	15.4	626.2	2620.9	19.6	5.72	3236.7	3262.1
Sehb Ighar	310	725.7	6135.7	455.6	21.7	6701.7	7179
Swiwina	0.2	101.5	2635.8	0.1	0	2745.8	2745.9
Zone Irrigueé	512.5	1400.3	9869	810.7	96.2	10874	11780.9
Gaadat Nsara	11.8	1084.6	4361.2	31.1	0	5428.4	5459.5
Mesakhskha	26.6	4379.1	11983.2	90.7	1.72	16295.1	16387.5
El Gour	29.3	221.3	3136.9	84	23.8	3279	3386.8
Lbiayad	8.7	79.7	3201.6	65.4	0.00	3224.6	3290
Khoui Lamaiz	0.4	15.4	2736.8	15.2	15.1	2731.1	2761.4
Koui Sedrat	0	6.9	2072.9	21.3	1.1	2061.9	2084.3
Sebh Laatamna	2.4	79.3	4026	8	0	4099.4	4107.4
Chebkat Kaddour	0	57.23	1075.3	0.63	0.00	1130.9	1131.6
Fritiss	30	2726.8	15285.5	76.5	21.4	17945.6	18043.5
Nkhila	4.6	465.1	5263.1	9.3	3.6	5719	5731.9
Khoua Od Biad	1.2	46.7	4505.2	51.7	10.5	4504.2	4566.4
Oglat Sedra	0.8	1050.7	3968.4	8.4	6.8	5019.6	5034.9
Dhar El Gaada	46.5	9398.1	9553.5	31.9	0.00	18975.9	19007.8

When the changes in land use are shown graphically, pasture by pasture, the major increases in field extent occur in the northern sector of the study area. More favourable conditions for agricultural production exist there due to a slightly higher rainfall regime (170 mm/yr) and the predominant soil in the area being less saline (Chiche, 1992). Figure 2 illustrates the degree and distribution of increases in agricultural fields, both irrigated and non-irrigated, between the two dates.

Figure 2 - Increases in agricultural fields between 1988 and 2000 as a % of total pasture area.



5. DISCUSSION

Data on agricultural expansion, as collected by the local agricultural research station through farmer interviews, had indicated significant increases on a yearly basis. Expected rates were quoted as being between 300 and 400 ha annually. Utilising the satellite imagery indicated a much lower degree of expansion over a twelve year time frame. The combined total of newly created irrigated and rainfed fields came to 1335.47 ha. This represented an expansion of agricultural lands onto lands previously categorised as rangelands of 0.9% of the total Aïn Béni Mathar area. Of the new fields, 61.5% are irrigated whilst only 38.5% are considered rainfed. The discrepancy indicated between these results and previous studies could be explained by several factors. It is possible that the rate of expansion has varied substantially on a yearly basis and has only recently reached the levels outlined through farmer interviews. Due to documented fluctuations in climatic conditions (INRA-Oujda, 2000) over the twelve year period, such a variation is more probable than not however this could be clarified either by further interviewing or by analysis of an additional image dated between 1988 and 2000. Limited errors of exclusion generated during the stages of image processing might contribute but would not explain such a large discrepancy Temporary and permanent field abandonment could also be a contributing factor however at present no information is available through farmer interviews regarding this phenomenon.

The distribution of new agricultural areas depended upon the type of field being developed. New irrigated fields remained close to existing ones in the pre-defined irrigation zone presumably due to the cost of infrastructure needed to manage such fields. Newly developed areas categorised as rainfed fields however were not always found close to existing agriculture. Instead, they were more likely to be found on areas seen in the 1988 image as being covered by good to medium rangeland. These tended to be located in areas of dense drainage, for example wadi beds and tributaries that had previously gained access to increased volumes of precipitation runoff. A risk associated with such developments is that these areas are often the most environmentally sensitive. Once established these new areas showed a pattern of nucleation.

As mentioned previously, the land cover classes differed for both years. Whereas a 'medium range' category existed from the 1988 image, no similar degree of natural rangeland vegetation was identified in the 2000 image (Table2).

TABLE 2 – LAND COVER CHANGES IN AÏN BÉNI MATHAR, 1988 – 2000.

Year	Irrigated Fields		New Fields		Medium Range		Poor Range	
	Ha	%	Ha	%	Ha	%	Ha	%
1988	1091	0.8	N/A	N/A	27659	18.9	117496	80.3
2000	1903	1.3	509	0.35	N/A	N/A	143914	98.4

The areas delineated as medium range were calculated using the NDVI study results. As such the image data was normalised and was comparable between the two dates. It is expected that variations would occur in the quality of natural vegetation over time due to both natural events and from variations caused by datasets derived from different satellite image sensors. It might even be expected to introduce some error into the land cover classification by level slicing using manual interpretation techniques. It is though highly unusual for these factors to account for such dramatic changes as witnessed by the total loss of medium quality rangelands to poor rangelands between 1988 and 2000. This difference indicates a loss of 27,659 ha of medium range at a time when agro-pastoralists rely on a plentiful supply of grazeable natural pastures to offset the costs incurred by purchasing feed supplements over the summer. This loss may be accountable to the below average rainfall that this region has experienced during the last two years or to over-grazing in these better areas as the greater area of poor range is exhausted. It is suggested that this difference is far more significant in terms of the overall land use dynamics than that as indicated by the farmer interviewing related to rangeland loss due to agricultural encroachment.

6. CONCLUSION

The area known as Aïn Béni Mathar has indeed seen dramatic changes in its traditional agro-pastoralist ecosystem. The exploitation and conversion of natural rangelands for field based agricultural production has not been seen to be as important as indicated by farmer's surveys. Approximately 1% of the total study area has been converted during a twelve year period. The apparent loss of nearly 28,000 ha of good rangeland, even if only temporary, will have far greater implications for the long-term sustainability of the area's farming system and community property. Based on the information collected from farmer interviews, the expansion of agriculture over the previous 12 years does not seem to have been a continuous one. Non-irrigated field development is closely associated with

seasonal variations in precipitation and increases in irrigated field production are resultant from either the need to substitute income normally associated with sheep production or in times of surplus income. As the predominant location of irrigated field expansion lies within the already established irrigation zone, this form of field expansion cannot be considered a risk to existing rangeland areas. Likewise newly developed fields reliant on precipitation constitute an insignificant degree of change.

The use of remotely sensed imagery has been shown to be useful in quantifying land use dynamics within the study area, questioning the accuracy of data derived from farmer interviews and raising issues related to the patterns and relative extents of agricultural expansionism in the Aïn Béni Mathar rangelands.

7. ACKNOWLEDGEMENTS

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This paper is dedicated to the memory Mustapha Bounejmate, a great colleague, friend and traveling companion.

”Biz millah Mustapha”

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