4.6. Irrigated area by NOAA-Landsat upscaling techniques

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4.6.1. Upscaling from Landsat to NOAA pixel size

Although LANDSAT images give good accuracy in calculating irrigated areas due to the small pixel size of approximately 30x30 m, the availability of images is less than that of NOAA images. However, while NOAA images are freely available and the satellites pass overhead every day, the pixel size is approximately 1.0 km^2. By making comparisons of NOAA and LANDSAT images for the same time period, it is possible to obtain comparable information on irrigated and generate time sequence data.

The comparison requires certain calibrations of both images to be made. It is recognized that NDVI values for NOAA images give an unadjusted value for irrigated area that is much lower than LANDSAT because unirrigated areas within irrigation systems will reduce NDVI values for the entire pixel. This is particularly true where irrigation is by groundwater with large unirrigated areas between irrigated fields.

The following assumptions can be made in such comparison:

- All values of NOAA NDVI pixels less than or equal to 0.06 are considered to represent non-irrigated areas. This threshold is quite sensitive and therefore critical to the comparison of NOAA and LANDSAT images.

- For the NOAA NDVI values greater than 0.06, the irrigated area I is calculated as $I = A\sum_j f_{gi} n_i$ where A is the area of a pixel, while f_g is taken as c*NDVI.

- The proportionality constant c is then determined by regression against the areas as determined in the Landsat image. This constant should have a value of approximately 3 but must be determined for each calibration because it is sensitive to atmospheric and other transient conditions (see figure 4.18).

A Landsat 7 image of August 1 1999 was used to calculate the irrigated and non-irrigated areas through standard GIS/RS techniques. Five areas were selected: Borkhar, Nekouabad Left and Right Bank, Abshar Left and Right Bank. A set of 5 NOAA images was used (July 7, 8, 25 and August 21 and 29) in the calibration procedure as outlined above. The results of the calculations are summarized in table 4.9. The uncalibrated NDVI values for the main irrigation systems for July 25 1999 are shown in figure 4.17, ranging from 0.0 to 0.38.

Table 4.9 shows that there is a clear increase in area from July 7 to August 29. Comparison with the Landsat values can be made through the averages of the 5 images or through the use of the July 25 NOAA image. Figure 4.18 shows the result of the regression analysis based on average NDVI results of the five NOAA images compared to the LANDSAT image. Theoretical considerations show that the constant should be a number close to 3, and the proportionality constant was determined to be about 2.7 for this time period. The method using the average of 5 images seems to be better than using one single image, and table 4.10 shows the estimated areas using this procedure for 1999 data.

Figure 4.17. NOAA NDVI values in the main irrigation districts on 25-7-1999.

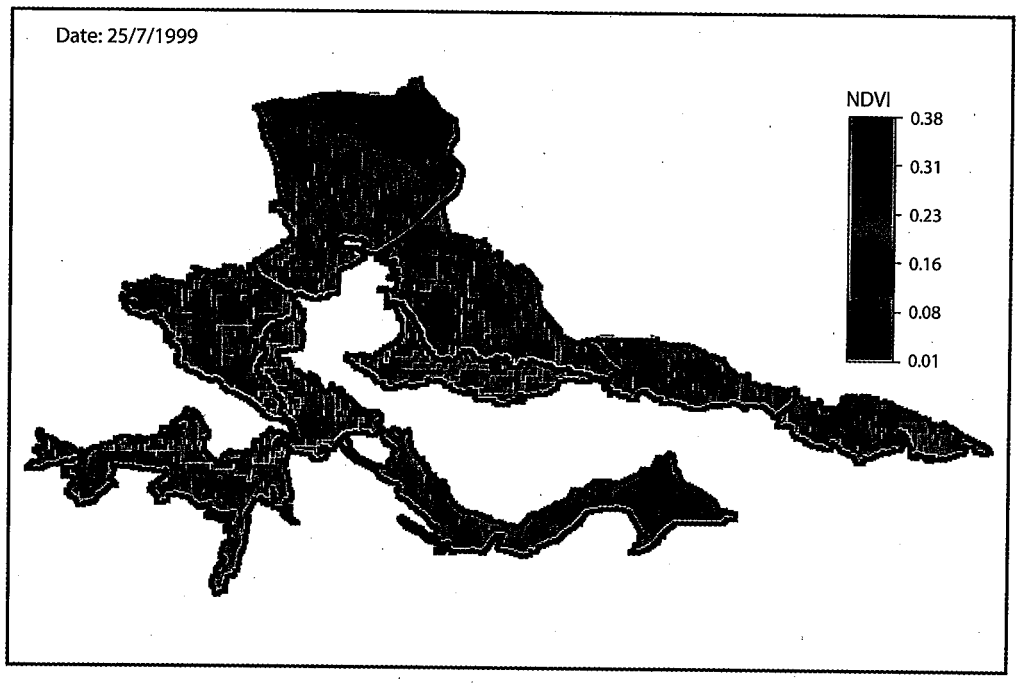


Table 4.9. Comparison of the LANDSAT and five NOAA image results (areas in ha).

	07-Jul	08-Jul	25-Jul	21-Aug	29-Aug	Average	Std. Dev	Landsat 7
Borkhar	3,813	7,225	5,462	7,790	8,681	6,594	1,949	15,915
Nekou-L	6,693	9,590	8,609	11,644	11,094	9,526	1,988	27,912
Nekou-R	3,415	4,469	5,174	5,985	5,912	4,991	1,075	12,922
Abshar-R	3,312	4,053	4,142	5,833	5,684	4,605	1,103	12,382
Abshar-L	6,187	7,836	7,235	10,134	10,689	8,416	1,925	22,874
Totals	23,420	33,173	30,622	41,386	42,060	34,132		92,005

In general, the errors are larger for Borkhar, Lenjanat and Mahyar where the choice of NOAA NDVI threshold (0.06 in this case) appears to be critical. These districts have less uniform surface water irrigation and large parts of these areas are irrigated with groundwater. The table shows that it is not advisable to make area calculations based on a single NOAA image.

4.6.2. Time series assessment of irrigated areas using NOAA NDVI data.

Based on the approach described above, it is possible to repeat this exercise for a series of NOAA images to understand the annual cropping cycle. Using a total of 26 NOAA images for 1995, roughly one every two weeks depending on cloud and other atmospheric conditions, the changes in irrigated area can be clearly determined.

Figure 4.18. Comparison of NOAA NDVI values and LANDSAT irrigated areas.

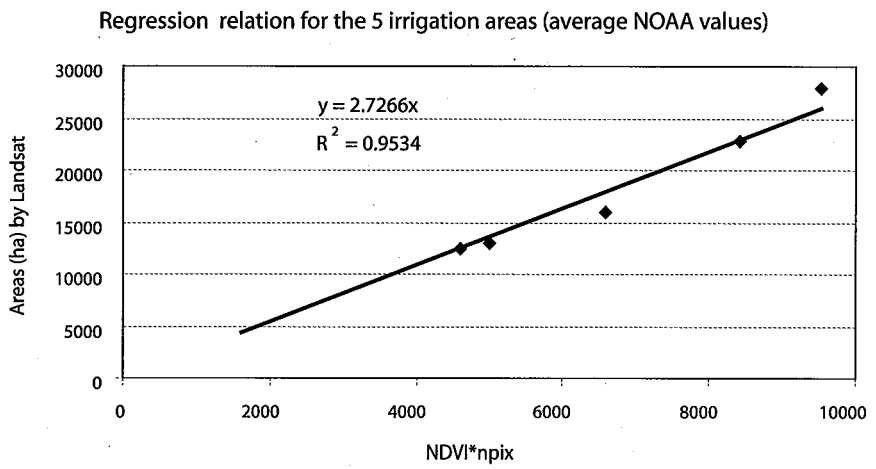


Table 4.10. Irrigated areas from NOAA after calibration for the period July 7 1999 to August 29 1999 (all areas in ha).

	07-Jul 7	08-Jul 8	25- Jul 25	21-Aug 52	29-Aug 60	avg	Landsat7 (1/8/1999)
Borkhar	0397	19700	14893	21240	23670	17980	15915
Lenjanat	4204	16537	12172	16602	16741	13251	
Nekou-L	18249	26148	23473	31749	30249	25974	27912
Nekou-R	9311	12185	14107	16319	16120	13608	12922
Abshar-R	9030	11051	11294	15904	15498	12555	12382
Abshar-L	16869	21366	19727	27631	29145	22948	22874
Rudasht-W	4624	6748	4390	5554	6184	5500	
Rudasht-E	6718	8681	7490	9011	9450	8270	
Mahyar	1775	5919	4297	7861	8954	5761	

The results for the irrigated area patterns of 1995 are shown in figure 4.19. In general, the pattern is clear. The irrigated area increases until May, and then there is a sudden drop associated with the harvesting of winter crops, after which the values rise again in response to the expansion of summer crops. The methodology seems to be able to distinguish different agricultural conditions in different irrigation systems. However, it should be noted that the calibration is really only valid for the summer crop period during the maximum NDVI period

and it is not correct to assume that the calibration is valid for all times of the year. When the crop is in its initial stage, the relation between NDVI and irrigated area is not straightforward and needs further calibration against Landsat images of different seasons. It is probably best to interpret irrigated areas using the maxima in the graphs of figure 4.19 as the actual irrigated areas, and place less emphasis on the areas estimated before and after these maxima.

The pattern is uniform in Nekouabad for both the Right and Left bank systems. There is a steep rise in NDVI values and a sudden drop towards the end of May, indicating simultaneous harvesting of all winter crops (mainly wheat and barley) in the system, combined with flooding of areas in preparation for rice planting. After this, NDVI values rise again in response to the growth of the summer crops (mainly rice, corn, potato and onion). There is always some land in cultivation (orchards and alfalfa) and this is captured in the NOAA data. Harvesting of the summer crops takes place gradually, leading to a steady decline in NDVI values after August.

The Abshar Right Bank system has higher NDVI values than the Left Bank, which has a higher proportion of unirrigated rocky areas. The cropping pattern changes are similar to that of the Nekouabad systems in winter. However, NDVI values build up much more slowly for the summer crops and the maximum summer NDVI values are lower than for winter. This is probably caused by the relatively more diverse cropping patterns (more corn and vegetables) as compared to the Nekouabad system where rice is dominant.

Both Rudasht systems show a much smaller increase in summer crops after the harvesting of winter wheat and barley. This is indicative of tail-end conditions where water supplies are less, and where salinity affects cropping opportunities for farmers.

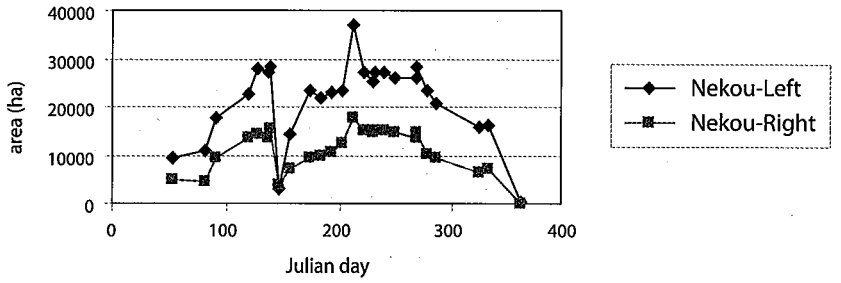
Lenjanat is a hybrid system, partly irrigated from the Zayandeh Rud, partly from tubewells. The overall pattern of cropped area is similar to Nekouabad, but there is more fluctuation in individual values reflecting the complication of accurately assessing irrigated area when the irrigated patches are fragmented. This is even truer for Borkhar and Mahyar, where the data appear to have a lot of variability. It seems that cropping intensity in Mahyar is quite low. Nevertheless, the dual seasonality is still captured, which reflects the actual irrigation practices.

4.6.3. Long-Term Changes in Irrigated Area

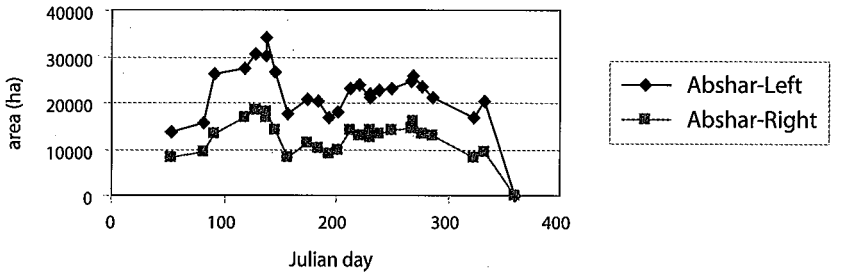
Comparison between different years becomes possible using NOAA data. As an example, a comparison is made between the actual irrigated areas of July-August 1995 (average of 7 images) and the areas of the corresponding time period in 1999 (average of 5 images), which was also used in the calibration process. The results are summarized in table 4.11 and figure 4.20. The greatest increases in irrigated area have occurred in Mahyar and Borkhar, where new canals have been built to supplement existing groundwater development. Abshar has experienced significant increases in groundwater development, greater in the Left Bank than the Right Bank. Nekouabad has seen little increase in irrigated area, a reflection of the intensive irrigation in that area that had developed before 1995. Rudasht systems have seen little or no growth, presumably because surface water availability is less and groundwater is too saline for widespread exploitation and, for Rudasht East, there appears to have been a decrease in the irrigated area.

Figure 4.19. Seasonal variations in irrigated area estimated from NOAA NDVI data.

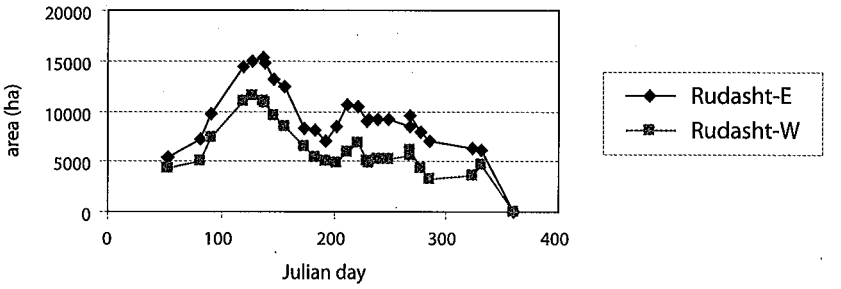
Nekouabad (1995)



Abshar (1995)



Rudasht (1995)



(1995)

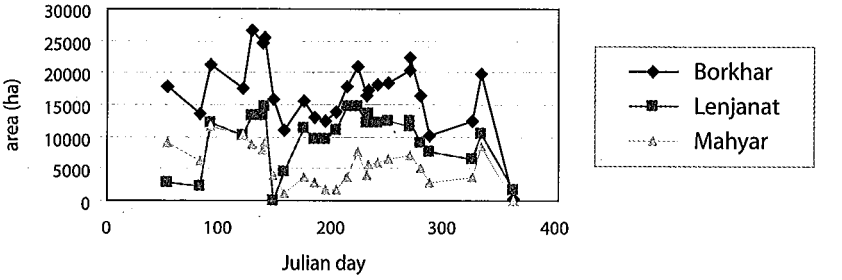


Table 4.11. Comparison of the irrigated areas for the periods July-August 1995 (7 images) and the calibration period July-August 1999 (5 images).

	1995	1999	Increase	%
Lenjanat	11,844	13,251	1,407	11.9
Mahyar	4,233	5,761	1,528	36.1
Nekouabad Left	25,015	25,974	959	3.8
Nekouabad Right	13,225	13,608	383	2.9
Borkhar	15,992	17,980	1,988	12.4
Abshah Left	20,760	22,948	2,188	10.5
Abshah Right	11,701	12,555	854	7.3
Rudasht West	5,340	5,500	160	3.0
Rudasht East	8,801	8,270	-531	-6.0
Total	116,911	125,847	8,936	7.6

Figure 4.20. Comparison of the actual irrigated areas for the periods July-August 1995 and 1999.

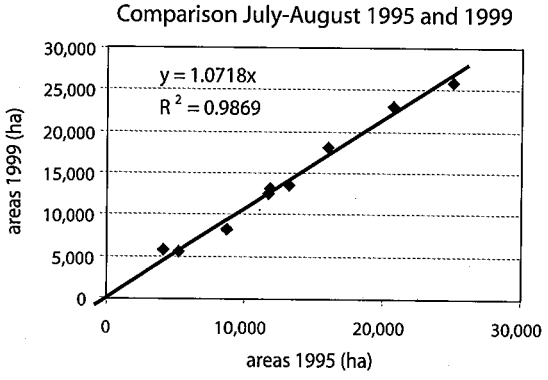


Figure 4.20 shows that the actual irrigated area was 7 percent higher in 1999 than in 1995, amounting to a total increase of 9000 ha. The quality of the regression line of figure 4.2 is very good, which underlines the consistency of the methodology outlined in this paper.

Using NOAA NDVI to estimate total cropped area, delimitation of different irrigation seasons within a year, and comparison of cropped areas from one year to another makes it a very powerful tool for assessing irrigation conditions at basin and system levels. NOAA images are readily available and the processing is quite straightforward. This means that it is a technique that can be used easily over wide areas.