4.5. Crop and Land Cover Classification by Landsat 7, and determination of irrigated areas.

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Remote sensing provides one way of obtaining more accurate information on total cropped area and crop types in irrigated areas. The technique is particularly well suited to arid and semi-arid areas where almost all vegetative growth is associated with irrigation. Using a LANDSAT 7 image from July 2, 2000, efforts were made to reconcile data obtained from field surveys and data from both LANDSAT and NOAA images.

4.5.1. Crop and Land Cover Classification

Using a supervised classification system, training areas were selected and initial classifications were made to determine the validity of the classes. After merging several classes and testing several new classes, a final classification system was made. All seven Landsat bands were used in the determination of the feature statistics. The final classification was made with the minimum distance algorithm.

One problem with this classification has been that the cropping pattern of July shows a transition from winter to summer crops. Some areas still show winter wheat and barley, others are fallow between season, while rice is still young and difficult to distinguish from other grain crops and alfalfa.

Ground data from GPS surveys were used to both georeference the satellite images and also delimit the boundaries of fields where crop types had been verified. It is recommended not to take a single point in the middle of the fields, but to try to take coordinates of all corners. Based on the combination of field data and analysis of the images, a total of 20 land cover classes were determined with each land cover having a specific set of seven vectors, one for each LANDSAT band.

The classification results with the 20 sample classes are shown in figures 13 to 16 based on the initial classification method. Some of these classes are very close to each other in terms of the spectral values and it may be hard to distinguish between them. It depends a lot on the final purpose of the classification. From an agricultural perspective, we are less interested in distinguishing non-agricultural land covers such as roads, mountains, and urban areas, and we do not particularly worry about differences between different types of bare soil. It is therefore possible to reduce the number of classes if the end use of the classification is known.

Figure 4.13 shows an overview of the Borkhar, Lenjanat, Abshar and Nekouabad Districts. The green colors show active vegetation, while the light blue color should be interpreted as irrigated land with vegetation (mainly rice) in the early growing stage. The light blue areas clearly show that irrigation took place in these areas in the last weeks of June 2000, when water supplies from the Zayandeh Rud were already getting low. The Borkhar irrigation district clearly shows much less green vegetation on a background of bare, gypsiferous soils.

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Figure 4.13. Land cover classification with different soil and vegetation types.

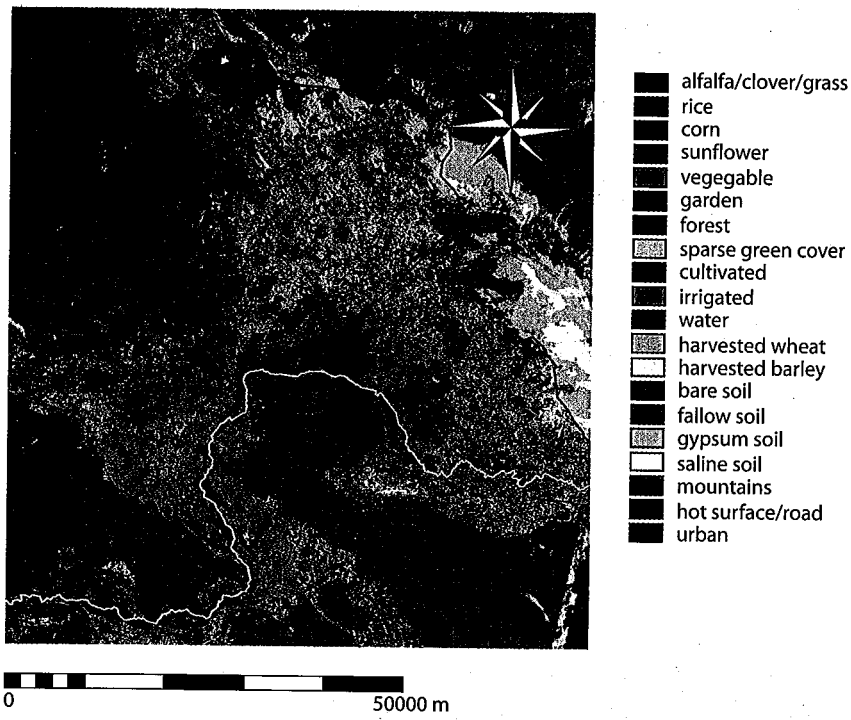


Figure 4.14. Land cover and crop types of the Borkhar District.

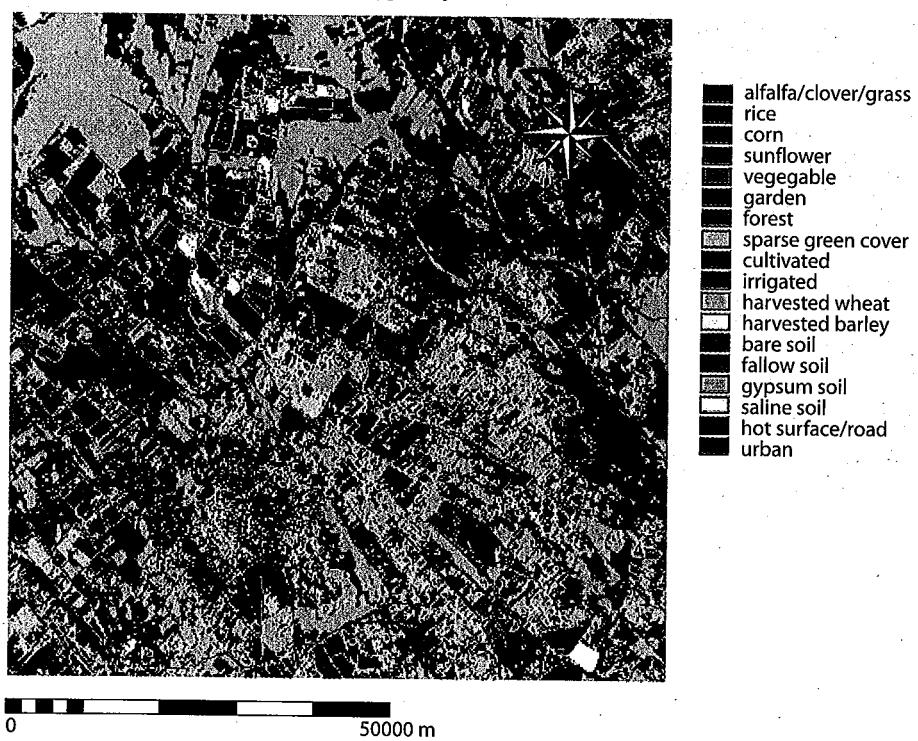


Figure 4.14 shows a detailed view of a northern Borkhar farm area. Irrigated farmland only is a fraction of the total and is typical of an area irrigated using tubewells. Surface irrigation is normally contiguous while tubewell irrigation tends to be patchy. Water shortage and poor soil conditions are clearly limiting factors in this district.

In Figure 4.15, a detailed view is given of the situation in the Abshar Left and Right irrigation districts. Abshar Right Bank shows freshly irrigated land near the Zayandeh Rud and in the south near the main diversion channel. It is also clear that there are more patches of bare/uncultivated land in Abshar Right Bank than in Abshar Left Bank. It appears that there is not much irrigation for the summer season in Abshar Left at this stage.

Finally, Figure 4.16 shows Nekouabad Right Bank, where normal irrigation was taking place. All the suitable land is utilized and the few brownish areas are rock outcrops and hills. Misclassification occurs on the hill slopes in the northeastern part of the area, where a few blue spots indicate the presence of irrigation. The reason for this is that hill slopes are highly heterogeneous, because of shade. Slopes exposed to the sun become very hot, while those in the shade remain very cool. The properties, cool and dark, are generally those of watered surfaces, because these tend to be cooler than their environment and because they have low reflective characteristics (they absorb the incident light).

Figure 4.15. Detailed view of the Abshar crop classification.

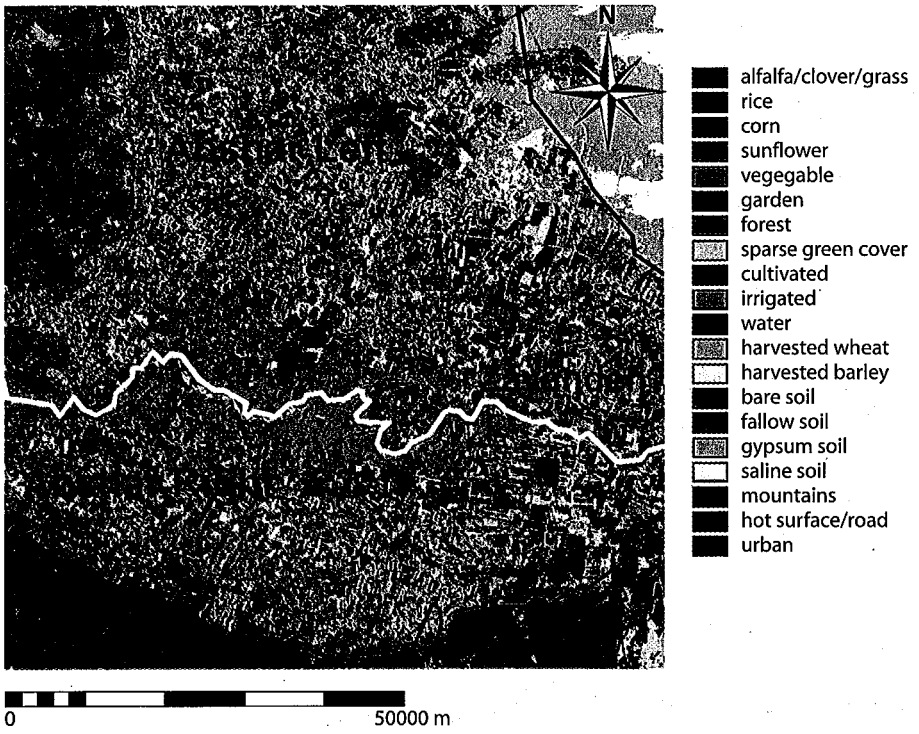
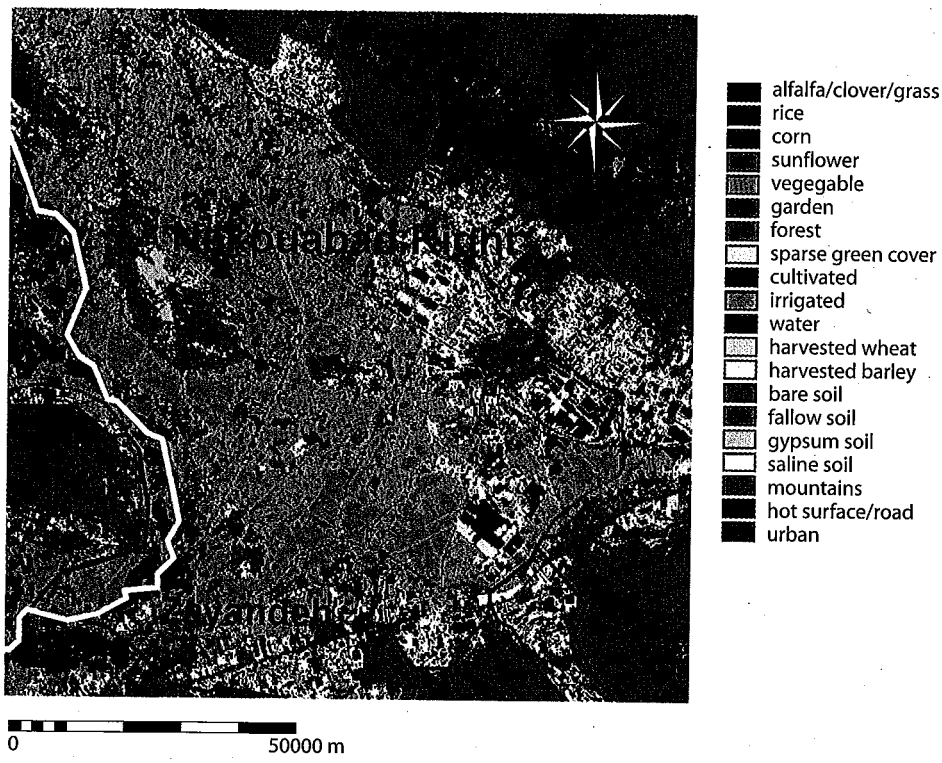


Figure 4.16. Detailed view of the Nekouabad Right crop classification.



4.5.2. Total Irrigated Area Statistics

Statistics with respect to areas and crop type for the districts were obtained by crossing the raster map with the irrigation district raster map. The results with respect to crop type and total irrigated area per district were compared with those of previous studies, and included both NOAA/AVHRR and conventional agricultural district statistics.

The areas for each class or crop type can be found through some simple GIS crossing operations. Table 4.7 shows the results. The classification based on 13 classes has been taken to subdivide crops and soil types. Classes 12 and 13 are not part of the instantaneous irrigated area (cropped area) as viewed by the satellite, and these were therefore taken out of the sum for the cropped area. This approach has the advantage that comparison can then be made with other satellite methods that also make use of NDVI analyses. It should also be noted that there is a large area classified as sparse green cover. A number of pixels in this category are probably of mixed origin: part vegetation, part bare soil or road. This category therefore introduces another uncertainty in the total irrigated area assessment, probably leading to a slight overestimation of the irrigated area estimates.

Table 4.7. Area per class for the irrigation districts fully covered by the image. Also shown are the total irrigated areas and the gross areas of the districts (July 2000).

Area	Lenjanat (ha)	Nekleft (ha)	Nekright (ha)	Borkhar (ha)	Absright (ha)	Absleft (ha)	Total (ha)
1 Alfalfa/rice/irrigated	4,741	9,894	6,587	1,600	3,020	4,147	2,9989
2 Corn	1,054	85	240	2,853	961	2,086	7279
3 Sunflower	1,362	4,832	1,852	3,501	2,098	4,894	1,8539
4 Garden	856	6,994	1,612	2,669	2,003	2,923	1,7057
5 Forest	305	574	278	505	266	279	2207
6 Sparse green cover	2,290	4,168	1,714	5,547	3,315	6,493	23,527
7 Water	198	45	16	15	1	3	278
Irrigated area	10,806	26,592	12,299	16,690	11,664	20,825	98,876
8 Harvested wheat	1,797	951	728	8,533	1,484	4,194	17,687
9 Harvested barley	68	30	128	992	381	1,242	2,841
10 Bare soil	9,116	5,520	2,897	40,972	4,753	14,324	77,582
11 Gypsum oil	14	43	77	8,827	83	1,231	10,275
12 Saline soil	1	18	20	117	44	11	211
13 Heterogeneous	5,970	5,725	4,384	7,828	3,582	7,118	34,607
Non irrigated	16,966	12,287	8,234	67,269	10,327	28,120	143,203
Total area	27,772	38,879	20,533	83,959	21,991	48,945	242,079

Much as we might like to feel that LANDSAT image analysis gives accurate results concerning the irrigated area, it is insufficient to merely make this assumption where other data are available, especially if the analysis is based on a single date image rather than a multi-temporal sequence.

As a result of other project activities, data are available from a variety of other sources that allow us to make a cross-check of the different results. Table 4.8 shows results from nine different efforts to determine total irrigated area, both from remotely sensed data and from secondary sources.

The results show that the variability of methods 1-5 (based on remote sensing) is much less than the range in values of methods 6-8 (secondary statistics and older remote sensing analysis). The explanation for the difference between 6 and 7 lies in the trend observed by Sally et al. (2001). However, not much of a trend is visible in the remote sensing analysis (methods 1-5), based on 1995, 1999 and 2000 figures.

The data from the District Agricultural Statistics sources do not distinguish between winter and summer cropping patterns, and this makes some of the comparison rather difficult, particularly when based on one image in the transition between winter and summer. Some plots are cultivated with two crops a year, others with only one, so no direct comparison is really possible.

It is therefore recommended to continue with the remote sensing method during various parts of the year to check both on winter and summer crop statistics. This will still require

Table 4.8. Comparison of total area calculations with those by NOAA/AVHRR methods and district agricultural statistics.

Satellite	Lenjanat (ha)	Nekleft (ha)	Nekright (ha)	Borkhar (ha)	Absright (ha)	Absleft (ha)
1 Landsat 7 2/7/00	10,805	26,593	12,300	16,691	11,663	20,825
2 Landsat 7 1/8/99		27,912	12,922	15,915	12,382	22,874
3 Landsat 7 1/8/99	11,673	28,867	13,859	25,920	14,547	27,605
4 NOAA Jul-Aug, 1999	13,251	25,974	13,608	17,980	12,555	22,948
5 NOAA Jul-Aug, 1995	11,844	25,015	13,225	15,992	11,701	20,760
6 NOAA 95 (SEBAL)		40,141	15,203		11,688	27,172
7 Agric. statistics (yr 2001)		48,000	13,500		15,000	15,000
8 Agric. statistics (1999-2000)		30,313	16,631		16,247	38,754
9 Agric. statistics (1994-1995)		27,268	11,376		9,296	21,612

1. Landsat 7 ETM (2 July 2000) study presented in this report.
2. Based on analysis of NDVI values of Landsat 7 image (1 Aug 1999) (Gieske et al. 2002).
3. Landsat 7 ETM (1 August 1999). Classification by A.R. Mamanpoush.
4. NOAA/AVHRR upscaled from Landsat (Gieske et al. 2002).
5. NOAA/AVHRR uspcaled from Landsat (Gieske et al. 2002).
6. NOAA/AVHRR 1995 cropped area (Droogers et al. 2001).
7. Command areas, District Agricultural Statistics (Sally et al. 2001).
8. District Agricultural Statistics 1999-2000 (Sally et al. 2001).
9. District Agricultural Statistics 1994-1995 (Sally et al. 2001).

fieldwork to gather actual crop data for classification purposes and to interview farmers about past cropping practices. Detailed crop comparison is less useful at this stage in view of these large differences in values for total irrigated areas, particularly when making decisions about water allocation between different irrigation systems at different times of the year.

The secondary statistics show higher values of cropping than the remote sensing analysis in 2001 and 2000, especially at Nekouabad Left command area. They give lower estimates of cropped area for 1995. In contrast, the SEBAL estimates considerably exceed 1995 statistics and other values for Nekouabad Left, Nekouabad Right and Abshar Left. It is perhaps not surprising that NOAA and Landsat estimates are consistent, since NOAA is "calibrated" on Landsat. However, single-date analysis does not take into account variations in visible cropping intensity across seasons, during seasonal overlaps and with varying planting dates from year to year. Therefore, a multi-temporal analysis is potentially more useful in defining irrigated area and is investigated in the next section.