APPLICATION 26

Creating a mosaic using small format aerial photographs

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Summary

Small format aerial photography (SFAP) is a low cost, do-it-yourself technique to obtain actual data that can be used for a wide range of applications. For example to detect recent changes caused by disasters, like mudflows, flooding and earthquakes, but also to analyze urban changes, land degradation or land use changes over a longer period, when recent images are not yet available.

This exercise focuses on creating a photo mosaic of an area near to Lake Naivasha in Kenya where recent changes in land degradation have occurred. To correct the aerial photographs geometrically the projective transformation is used, as the area is almost flat. The coordinates of the tiepoints were collected in the field by GPS observations with a Garmin 12.

Getting started

This application is written for use with the ILWIS 3.0 software.

The data for this case study can be downloaded from the ILWIS Internet site at http://www.itc.nl/ilwis/. If you have already installed the data on your hard disk, you should start up ILWIS and change to the subdirectory where the data files for this chapter are stored. If you did not install the data for this case study yet, please download the data first.

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- Double-click the ILWIS icon on the desktop.
- Use the Navigator to go to the directory where the data files for this chapter are stored.

Now you are ready to start the exercises of this case study.

26.1 Introduction

Small format aerial photography (SFAP) offers a relatively low cost and simple do-it-yourself alternative to obtain up-to-date aerial photo coverage. The advantages make it very attractive to apply. However, every advantage has its disadvantage. One disadvantage should be acknowledged: the small format means that a relative small area is covered by a single photograph (as compared to the regular 23 cm aerial survey photography of the same scale).

Basically it is a technique best suited to relatively small areas, where no precision mapping is required, but where the photo is used as a source of thematic information. It can be particularly useful when no sufficiently recent large format photos of the appropriate scale and coverage can be procured, and when no time or money is available for ordering new large format aerial photography *(Hofstee, 1984).*

The cameras used are common off-the-shelf professional and good-quality amateur cameras, usually the 35 mm camera (image size 24 x 36 mm), or when available the 6 x 6 cm or 70 mm camera (image size 56 x 56 mm). The cameras have not been designed for metric qualities, therefore one cannot expect lens calibration, film flattening devices, or forward motion compensation. Nevertheless, e.g. for cases like mapping soil and vegetation patterns or urban changes the accuracy is acceptable *(Warner et al 1996).*

The photos can be georeferenced (and rectified) when the coordinates of a number of tiepoints are known. The simplest transformation is the projective transformation, which requires a minimum of 4 tiepoints and a flat terrain. Other transformations (e.g. direct linear) may be able to handle hilly terrain, but will need a digital terrain model to execute the transformation. A group of georeferenced photos can be assembled into a mosaic to cover a larger area. In this case 7 photos will be glued into a single mosaic.

The Longonot-Kijabe Hill area which is located just southeast of Lake Naivasha in Kenya, is currently suffering from severe wind erosion. An important constraint to the proper analysis of the wind erosion problems is the general lack of up-to-date information about the area.

This constraint includes the total absence of recent aerial photographs from the area. The most recent aerial photographs are from 1991, but the land degradation problems as a result of wind erosion started only after 1995. Landsat TM satellite images are available of 1989, 1995 and 2000 but they generally have a too low resolution for the analysis of wind erosion features. Under such circumstances there appears to be a clear need for the application of small format aerial photography (SFAP) - partly in complementary use with conventional aerial photography - to analyze and assess wind erosion problems.

26.2 Obtaining small format aerial photographs

The planning of a flight to obtain vertical SFAP is in principle the same as for a normal large format survey flight for vertical photography with stereoscopic coverage.

The prime factor to consider is the scale of the negatives of the photographs. The scale should be large enough to clearly see the details, which are needed in the interpretation of features, on a standard enlargement (e.g. size 10 x 15 cm, which means a factor 4.5 enlargement of the negative). A larger scale may be convenient to detect the features easily, but the cost is an increased number of photographs to cover the area and to interpret.

See Figure 1 for other factors to consider in the survey flight planning.

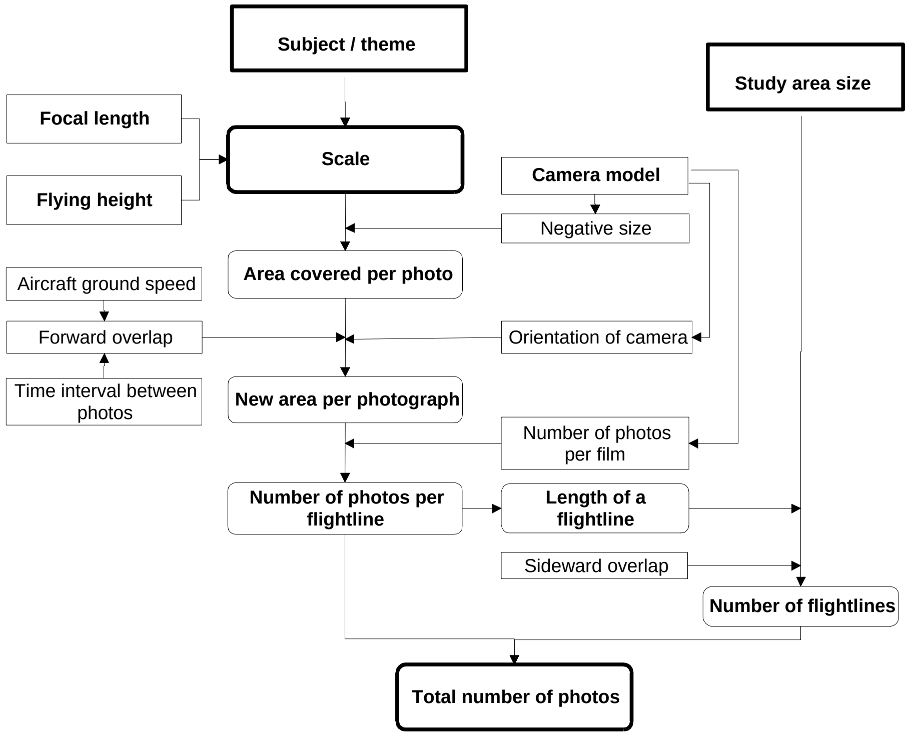

Figure 1: Small format vertical aerial photography flight planning. Please note that the orientation of the camera (parallel or perpendicular to the flight line) only applies to non-square formats, e.g. 24 x 36 mm.

26.3 Available data

In this exercise a limited number of photographs will be georeferenced to obtain a base map for the preparation of the map with the current status of land degradation. Seven photographs, the land use maps of 1991 and 2000 and the actual wind erosion map are available.

`Sfap1-7.tif`	Seven near vertical air photographs, with GPS tiepoint data, from the photo flight made on 23 September 2000 by Nagelhout. Flying height 700 m above the terrain, aircraft Cessna 182, door removed. Camera looking downwards vertically, attached to a tripod pointing through the door opening. Camera Minolta 7000 AF (image size 36 x 24 mm), 35 mm focal length lens, shutter speed 1/500 sec. Negative scale 1:20,000, hard copy photo print (10 x 15 cm) scale 1:4,500. The negatives are scanned with a resolution of 1200 dpi. To reduce the size (in Kbytes) of the data set with 50%, the operation Aggregate Map with a Group Factor 2 and Function `Average` of the value has been used, after which the images were exported as *.tif images.
`Detaila.tif`	Detail of photo `Sfap1` in the original scanned resolution.
`Detailb.tif`	Detail of the photos `Sfap4`, `Sfap2`, and `Sfap5` in the original scanned resolution.
`Land1991`	Land use map of 1991, digitized from an aerial photograph at scale 1:20,000 (Kenya Geomaps, Western Pipeline (number 291)).
`Land2000`	Land use map of 2000, digitized from the small format aerial photographs of 23 September 2000, scale 1:4,500.
`Wec2000`	Wind erosion map, current status (September 2000).

This exercise is mainly intended for georeferencing and mosaicking the photographs. The maps `Land1991`, `Land2000` and `Wec2000` are only for illustration purposes. The preparation of these maps requires a mirror stereoscope and all the original photographs, which are not included in this exercise.

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- Import the 7 images `Sfap1.tif` to `Sfap7.tif` into ILWIS 3.0.
- After importing the first image, the command on the Command line can be copied into a script to import the remaining images.
- Display the raster maps and zoom in to see the image details. Observe that the maps have no coordinates.

26.4 Tiepoint data

Table 1: `Sfap1` Tiepoint numbers, Row/Col number and X-, Y-coordinates.

#	Row	Col	X	Y
1	692	365	219311	9903182
2	699	183	219155	9903158
3	828	202	219185	9903041
4	839	50	219045	9903014
5	714	28	219013	9903117
6	647	530	219439	9903233
7	473	500	219404	9903372
8	502	326	219263	9903335
9	543	128	219095	9903285
10	376	83	219037	9903430
11	380	307	219240	9903438
12	307	476	219378	9903511
13	145	444	219338	9903656
14	221	120	219057	9903569
15	96	144	219061	9903691
16	36	249	219156	9903757
17	201	311	219224	9903595
18	838	382	219334	9903064
19	623	8	218985	9903209
20	561	1	218976	9903262

Table 2: `Sfap2` Tiepoint numbers, Row/Col number and X-, Y-coordinates.

#	Row	Col	X	Y
1	783	392	219338	9903656
2	625	339	219296	9903795
3	673	173	219156	9903757
4	513	127	219121	9903893
5	460	299	219267	9903933
6	416	459	219407	9903966
7	258	410	219372	9904106
8	305	252	219230	9904069
9	356	37	219050	9904027
10	750	63	219061	9903691
11	76	524	219484	9904268
12	104	362	219337	9904243
13	144	203	219197	9904208
14	190	34	219046	9904176
15	30	338	219318	9904314

Table 3: `Sfap3` Tiepoint numbers, Row/Col number and X-, Y-coordinates.

#	Row	Col	X	Y
1	782	400	219318	9904314
2	702	387	219300	9904380
3	696	204	219144	9904374
4	643	120	219070	9904409
5	659	20	218990	9904385
6	757	36	219012	9904306
7	505	531	219408	9904556
8	388	507	219383	9904660
9	358	403	219287	9904678
10	153	459	219325	9904875
11	162	407	219275	9904861
12	43	340	219204	9904973
13	216	201	219096	9904786
14	136	136	219030	9904855
15	149	15	218922	9904832
16	253	65	218982	9904736
17	385	196	219113	9904632

Table 4: `Sfap4` Tiepoint numbers, Row/Col number and X-,Y-coordinates.

#	Row	Col	X	Y
1	800	438	219121	9903893
2	770	292	218963	9903895
3	782	170	218844	9903857
4	619	153	218791	9904028
5	586	287	218916	9904084
6	667	403	219050	9904027
7	529	436	219046	9904176
8	531	364	218976	9904156
9	367	167	218752	9904272
10	359	281	218859	9904303
11	191	276	218815	9904466
12	200	120	218675	9904420
13	190	430	218959	9904495
14	305	433	218990	9904385
15	303	515	219070	9904409
16	388	435	219012	9904306
17	94	423	218932	9904585
18	92	268	218786	9904549
19	115	83	218619	9904485

Table 5: `Sfap5` Tiepoint numbers, Row/Col number and X-, Y-coordinates.

#	Row	Col	X	Y
1	50	440	219050	9904027
2	12	172	218791	9904028
3	170	333	218963	9903895
4	280	347	218988	9903793
5	294	221	218874	9903762
6	192	203	218844	9903857
7	184	54	218705	9903842
8	201	496	219121	9903893
9	345	511	219156	9903757
10	519	381	219057	9903569
11	523	187	218872	9903543
12	680	64	218769	9903372
13	677	172	218877	9903394
14	659	343	219037	9903430
15	808	256	218976	9903262
16	799	378	219095	9903285
17	670	542	219240	9903438
18	767	549	219263	9903335
19	763	13	218724	9903274
20	555	17	218714	9903487

Table 6: `Sfap6` Tiepoint numbers, Row/Col number and X-, Y-coordinates.

#	Row	Col	X	Y
1	56	128	218490	9903884
2	184	136	218504	9903740
3	359	266	218634	9903560
4	453	253	218625	9903470
5	522	214	218590	9903405
6	592	223	218600	9903341
7	647	316	218686	9903293
8	808	205	218591	9903147
9	102	263	218632	9903833
10	664	359	218724	9903274
11	94	333	218705	9903842
12	88	467	218844	9903857
13	173	499	218874	9903762
14	381	506	218872	9903543
15	435	343	218714	9903487
16	541	514	218877	9903394
17	562	406	218769	9903372
18	747	440	218802	9903201
19	731	529	218890	9903210

Table 7: `Sfap7` Tiepoint numbers, Row/Col number and X-, Y-coordinates.

#	Row	Col	X	Y
1	61	225	218435	9904397
2	206	242	218483	9904250
3	348	256	218525	9904111
4	422	301	218584	9904048
5	404	73	218370	9904021
6	27	414	218619	9904485
7	98	453	218675	9904420
8	244	507	218752	9904272
9	488	510	218791	9904028
10	575	171	218490	9903884
11	734	155	218504	9903740
12	656	312	218632	9903833
13	657	388	218705	9903842
14	668	532	218844	9903857
15	773	544	218874	9903762

26.5 Georeferencing images and applying a transformation

With the option Create GeoReference a georeference can be created for the images. After this process the maps can be resampled to new output maps and glued together to form a mosaic of the area. The individual maps were used to create the maps Wec2000 and Land2000.

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- Open the first image Sfap1 and create a georeference with the same name. Make sure that the option Georef Tiepoints is selected.
- Create a new coordinate system Longonot by clicking the Create button next to the Coordinate System list box.
- In the Create Coordinate System dialog box select the option CoordSystem Projection and enter the following data (obtained from the topographical map):
  - Min X, Y: 218200, 9903000
  - Max X, Y: 219600, 9905200
  - Projection: UTM
  - Ellipsoid: Clark 1880
  - Datum: Arc 1960
  - Area: Mean
- Make sure that the check box Northern Hemisphere is deselected, type 37 for the UTM zone and click OK in the Create Coordinate System dialog box.
- Click OK in the Create GeoReference dialog box. The image map Sfap1 is now displayed and the GeoReference Tiepoints Editor is opened.

Many reference points were chosen that could be clearly identified in the images. Normally these tiepoints consist of corners of farms, but also bushes, sharp corners of deflation trenches, electricity poles, constructional works, etc. were used. At every reference point an observation of 5 minutes was made in which the GPS (Garmin 12) calculated the position, averaging 30 epochs of 10 seconds each. The point observations were annotated on the hardcopy photograph.

The reasons why so many observations were made for every photograph are:

- to have a good distribution of tiepoints over the image
- observations that are not accurate enough will become visible in high DRow and/or high DCol values of the Georeference Tiepoints Editor and can be deactivated.

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- In the tiepoint Tables 1 – 7 you find the Row/Col numbers and their coordinates for every photo, i.e. ILWIS raster map. Use the row/col indicator on the lower left of the window to identify the tiepoints.
- Zoom in on the area, use the pointer to locate the tiepoints and click. The Add Tie Point dialog box appears. The row and column number of the selected pixel are already filled out. Now enter the correct X- and Y- coordinates.
  Note that the system assigns X- and Y- coordinates for the fifth tiepoint (for a projective transformation 4 points are sufficient to solve the transformation equation). Do not accept these values but fill in the values from the tables.
- In the GeoReference Tiepoint Editor open the Edit menu and select Transformation. The Transformation dialog box is opened.
- In the Transformation dialog box select the `Projective` transformation and click OK.
- Repeat the above-described procedure for image `Sfap2`.
- The tiepoints of the other 5 images have already been added. The resulting `*.grf` and `*.gr#` files are stored in a zip file called `Georeference26.zip`. Unzip this file into your ILWIS working directory to use them.
- In the Catalog, click with the right mouse button on raster map `Sfap3` and select Properties from the context-sensitive menu. The Properties sheet of raster map `Sfap3` is opened.
- In the Properties of Raster Map "Sfap3" sheet, change the GeoReference from `None` to `Sfap3` and click OK. Repeat this for the maps `Sfap4`, `Sfap5`, `Sfap6` and `Sfap7`.

! Pay attention to the places where the GPS observations have been made. Because of the reduction of the size of the images, for some points it will not be clear where exactly the observation was made.

As the imaged terrain is almost perfectly flat (all points are coplanar), the aerial photographs do not contain relief displacement. In such cases the photographs can be rectified by a simple projective transformation, using a perspective projection (from plane to plane).

- In the GeoReference Tiepoints Editor the Sigma is shown. If the sigma is too high (i.e. > `3.000`), some tiepoints have to be deselected

(by putting `False` in the column `Active`) for two reasons:
  - the tiepoint is not defined accurately enough, or
  - the GPS observations were not accurate enough.

- Find the points with a very high value in the `DRow` and/or `DCol` columns. These values are the deviations (measured in image pixels) from the ideal. Have a closer look at these points on the photo to see what could be the cause of the high values.
- Open the File menu and select Customize. The Customize GeoRefEditor appears.
- In the Customize GeoRefEditor you can customize the way in which tiepoints are displayed on the background image in the GeoReference Tiepoints Editor. By default good tiepoints are shown in green, medium good tiepoints are shown in yellow, 'bad' tiepoints are shown in red, and passive tiepoints are shown in blue.
- When the values are unacceptable (too high), change in the column `Active` the value `True` (=active) to `False` (= inactive) by clicking once in the cell and typing `F`. The sigma should decrease when such a tiepoint has been made inactive.
- Close the GeoReference Tiepoints Editor when you are finished.

For realistic results a minimum of 10 ground control points should be active. The best way to reach the compromise between the most active points and the lowest sigma is to deactivate the first point that reduces the sigma significantly (the point with a red color). Then repeat this procedure until the sigma does not change significantly. Make sure that the active points are still well distributed over the image.

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- Import the detail images `Detaila.tif` and `Detailb.tif`. These are small parts of the original images, scanned with a resolution of 1200 dpi and not reduced in size and quality.
- Display the images next to the raster maps `Sfap1`, `Sfap2`, `Sfap4`, and `Sfap5`.
- Locate the area of image `Detaila` on image `Sfap1`. Study the difference in pointing accuracy on the two images with such a different resolution. Repeat this with the other detail image `Detailb` on the images `Sfap4`, `Sfap2` and `Sfap5`.

26.6 Resampling the images and creating a mosaic

The georeferenced photo images might be resampled and displayed to apply the now defined transformation. It can be done individually to obtain a resampled map for every image or the maps can be glued together to get a mosaic of all the photographs. This resampling and gluing can be a lengthy process, but when done in a correct way, time can be saved.

First a georeference corners for one image will be defined and this image will be used as the first map in the gluing process. To avoid repetitive commands, a script is used to get the final map (which in this case is the photo mosaic).

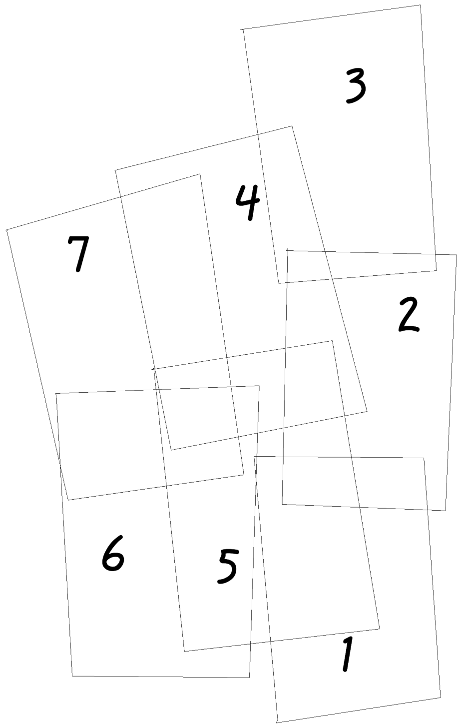

Figure 2: Location map of the georeferenced and resampled photos.

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- In the Catalog click with the right mouse button on `Sfap1` and select Image Processing, Resample from the context-sensitive menu. The Resample Map dialog box appears.
- In the Resample Map dialog box accept `Sfap1` as input Raster Map and `Nearest Neighbour` as Resampling Method.
- Type `Sfap1rs` for the Output Raster Map and create a GeoReference `Longonot` with a Pixel size of `1` meter and Coordinate System `Longonot`.

- Create a script `Mosaic` and enter the following command:
  `Mosaic:= MapGlue (Sfap1rs, Sfap2, Sfap3, Sfap4, Sfap5, Sfap6, Sfap7, Replace)`
- Execute the script and show the result. The orientation of the photographs should be similar to Figure 2.

! This process may take quite some time, depending on the specifications of your computer.

26.7 Application and analysis

During fieldwork observations have been made and annotated on the hard-copy photographs related to the type of degradation, the depth of it and some more properties. Afterwards a final wind erosion current status map `Wec2000` is created expressing the status in terms of severity.

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- To add polygon map `Wec2000` to the photo mosaic, first open the Properties sheet and select Coordinate System `Longonot`.
- Add `Wec2000` to the map window showing the photo mosaic. Differences of a few meters can be possible because of different tiepoints used for georeferencing.

In cases where degradation features were seen on more than 1 photograph, the one with tiepoints with the least error was taken as the base for the delineation.

Changes in land use between 1991 and 2000 do give interesting information about causes of recent land degradation in the Longonot area. Between 1991 and 2000 the arable fields area was reduced from 145 ha in 1991 to only 57 ha in 2000. Almost 50% of the deflation trenches are found in areas where agriculture was practiced in 1991.

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- Add polygon maps `Land1991` and `Land2000` to the map window. Select Boundaries Only and use `Blue` as Boundary Color for polygon map `Land1991` and `Green` as Boundary Color for polygon map `Land2000`.
- Zoom in on different places where land degradation occurs and analyze the land use changes.

References

Warner, W. S., R. W. Graham, et al. (1996). Small Format Aerial Photography. Caithess: Whittles, 1996. 348 pp.; 25 cm. ISBN 1-870325-56-7. (ITC Vubis 528.7)

Hofstee, P. (1984). Small format aerial photography: simple and cheap do-it-yourself technique. In: Cities vol 1 no.3, Feb 1984, pp.243-247.

http://www.gartrip.de/ An article in the GARtrip FAQ, subject Precision on the accuracy of the Garmin 12 (after disabling the selective availability in May 2000).