Chapter 3
Remote Sensing Data Sources

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Abstract Remote sensing techniques and data have been used in the Swiss National Forest Inventory (NFI) since its beginnings in the 1970s. Over the decades, the image data used has changed from first analogue black and white aerial images to digitised RGB true-colour images, and then to the digital colour infrared (CIR) sensor data in use today. In addition to applying aerial stereo-image-based interpretation on different sampling grids, area-wide data sets were developed and produced within the framework of the NFI4. In addition to aerial images, satellite images are also increasingly being used.

3.1 Introduction

Remote sensing techniques and data have been used in the Swiss NFI (NFI) since its beginnings in the 1970s. Over the decades, the image data used has changed from first analogue black and white aerial images to digitised RGB true-colour images, and then to the digital colour infrared (CIR) sensor data in use today. In addition to applying aerial stereo-image-based interpretation on different sampling grids, area-wide data sets were developed and produced within the framework of the NFI4.

In NFI1, aerial images served mainly to determine the forest area and therefore the forest sample-plot locations. It was also used to measure reference-point data for the subsequent assessments of samples in the field survey (Mahrer and Vollenweider 1983; Brassel and Lischke 2001).

In NFI2, the number of sample plots interpreted using analogue aerial images was increased eightfold, and the number of expensive field surveys could therefore be reduced (Köhl 1994). The catalogue of attributes measured in the aerial images was extended. The measured landscape attributes were selected to treat the forest as a discrete landscape element. If a sample plot in NFI1 and NFI2 was located in an area

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with no or only a few woody species, it was classified as *non-forest* and no further attributes were measured or recorded. If a sample plot evolved from *non-forest* to *forest*, no information about the previous land cover was recorded even though such information could have been relevant for subsequent NFI surveys.

NFI3 took into account dynamic landscape changes in space and time (Wildi and Brassel 1999). In addition to data on forest area, land-cover attributes were also determined in detail. The attributes were recorded irrespective of whether the sample plot was classified as forest or non-forest. The *forest/non-forest* decision was one of many products of aerial image interpretation (Mathys et al. 2005). Regarding the methodology and technology used, considerable improvements were made between the aerial image interpretation in NFI1 and that in NFI2. All data became available in digital form, from the oriented stereo models to topographic maps. The results of the interpretation and the decisions of the interpreters have been collected and fully documented in a geo-database.

The methods of aerial image interpretation used in NFI4 correspond to those used in NFI3 to a large degree (Hastedt et al. 2009). However, to be more flexible to apply different forest definitions, forest boundary lines are now mapped on a 100×100 m plot area and a *potential forest use* attribute is interpreted for *non-forest* plots. In the case of land uses that clearly do not permit forest use, the attribute *non-forest* is assigned. This makes it possible to apply forest definitions that differ from the Swiss definition (e.g. with a smaller crown cover), and to therefore obtain data comparable and harmonised with international standards. All other attributes are measured on the traditional 50×50 m area, as in previous Swiss inventories. The interpretation is carried out on the terrestrial grid, where the distance between the sample plots is 1.4 km. Since 2008, Leica ADS40/80 false-colour infrared images have been available, which are well suited for the interpretation of vegetation data. Moreover, aerial image interpretation is now performed completely within the framework of a Geographic Information System (ArcGIS with the extension Stereo Analyst).

The objectives of the aerial image interpretation are to:

- Classify plots as *forest* or as *non-forest* (*forest/non-forest* decision according to NFI criteria to optimise fieldwork).
- Assess the composition of land-cover classes regardless of the *forest/non-forest* decision.
- Identify reference points (coordinates, description) close to the centre of each sample plot. These reference points are used by the field survey teams to locate the sample-plot centre (SPC) of each plot.
- Generate training and validation data for area-wide products.

The results enable statistical analyses of certain variables for specific domains. Tables and maps showing means over domains can be produced. The availability of digital images and advances in methods of photogrammetry and remote sensing have enabled the development of workflows to derive not only sample data but also area-wide products with forest-related information. This area-wide data offers the potential for the spatially explicit analysis of forests. It can be used to quantify forest functions in cases where spatially explicit information is crucial, for example in

assessments of the protective function of forests or biodiversity. The main aim of developing area-wide data sets, however, is to integrate the data as auxiliary information in the two-phase estimation process to replace dense sampling during aerial image interpretation.

3.2 Data Sources

The ideal data for aerial image interpretation involving questions related to forestry and vegetation ecology is in the form of colour infrared (CIR) images. Vegetation has a maximum absorption in the blue and red bands of the electromagnetic spectrum. In the near-infrared band, more than 80% of the incident radiation is reflected. When the spectral bands of green, red and near-infrared are combined, these images enable a well-differentiated interpretation of trees and vegetation (Hildebrandt 1996).

The Swiss Federal Office of Topography (swisstopo) acquires digital aerial images covering the whole country every 3 years: every 6 years in summer (leaf-on conditions) and every 6 years in spring or autumn (leaf-off conditions). Since 2005, swisstopo has used a Leica Geosystems airborne digital sensor (ADS) camera to acquire the digital images. In contrast to frame cameras, the ADS camera is based on push-broom technology in which the sensor scans the earth's surface and produces long image strips backwards, nadir and forwards, simultaneously (Fig. 3.1).
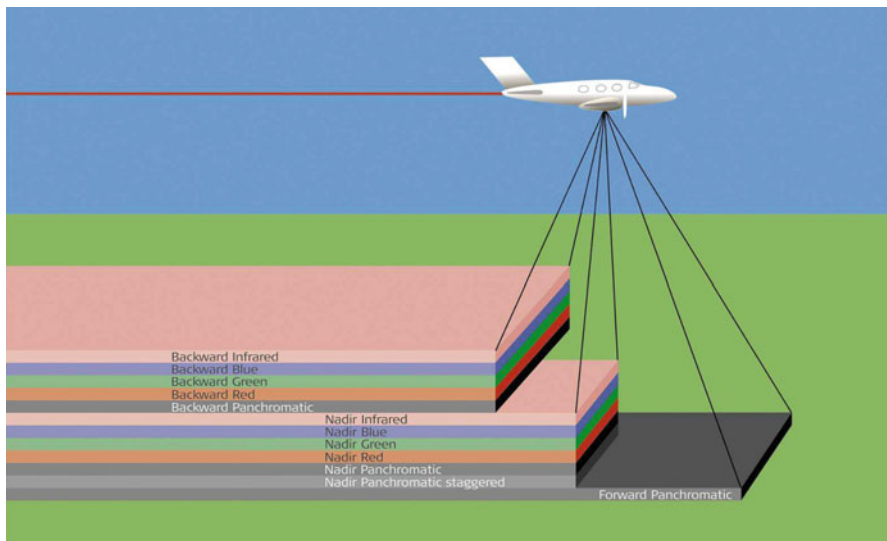

Fig. 3.1 Configuration of multiple linear charge-coupled device (CCD) arrays for the Leica airborne digital sensor (ADS). (Source: Leica Geosystems)
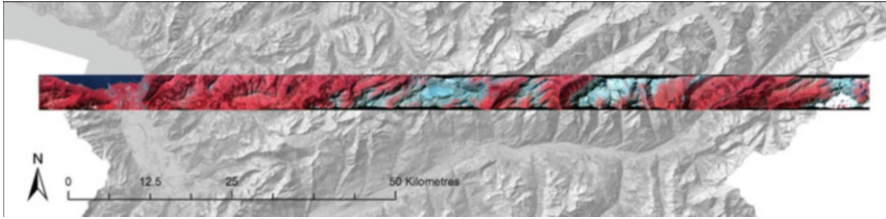
Fig. 3.2 Example of a colour infrared (CIR) airborne digital sensor (ADS) image strip (one image) with a ground coverage of 125×5 km
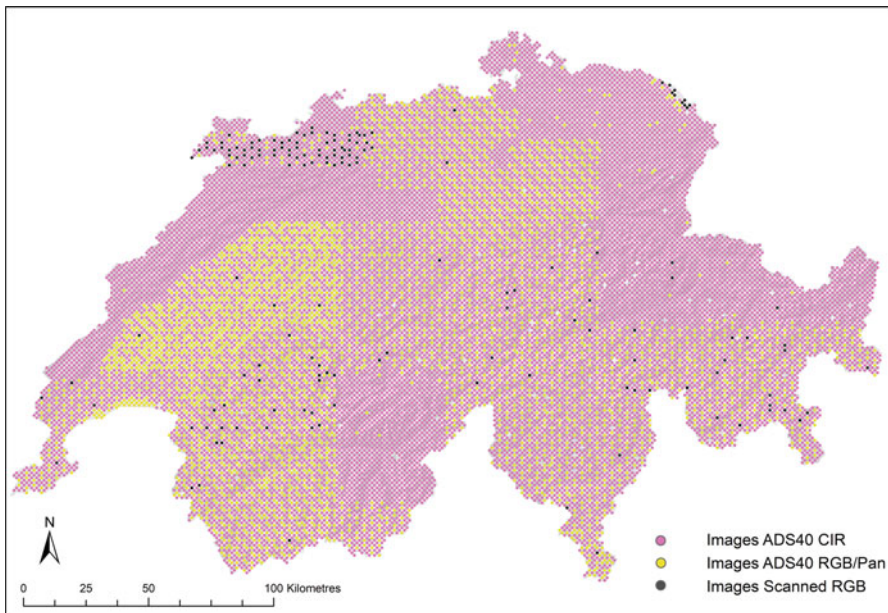

Fig. 3.3 Image material used in NFI4 aerial-image interpretation

Thus, the image strips can be visualised in three dimensions and digital surface models can be calculated.

Images from before 2005 are available as scanned true-colour (RGB) RC30 aerial frame images. Since 2005, the images have been available as digital ADS40 true-colour/panchromatic (RGB/Pan) stereo-image strips.

Colour infrared (CIR) stereo-image strips created with an updated sensor head for the ADS80 sensor have been available since 2008 (Fig. 3.2). The ADS40/80 images have a mean ground resolution of 25 cm (scale of ~1:15'000) in the Swiss Plateau, Jura and Pre-Alps and 50 cm (scale of ~1:30'000) in the Alps.

In NFI4, colour infrared images were used for aerial-image interpretation whenever possible (Fig. 3.3). More than 89% of the samples were interpreted with CIR ADS80 images, 20% with RGB/Pan images and less than 1% with scanned analogue
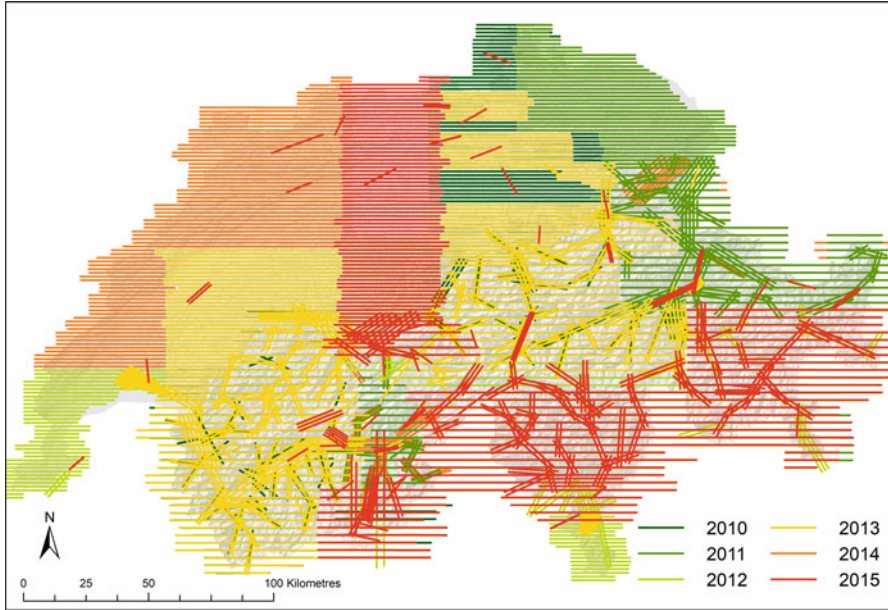
Fig. 3.4 Trajectories of ADS80 image strips used in NFI4 for area-wide products. Areas with denser strips have a resolution of 25 cm, whereas areas with sparser strips, mainly in mountainous regions, have a resolution of 50 cm

RGB images. Tests have shown that the type of image has no influence on the *forest/non-forest* decision. However, small gaps in the forest can be identified better with the newer images.

ADS80 CIR image data from the years 2010 to 2015, taken in the leaf-on months between May and September, were used to derive the area-wide products (Fig. 3.4)

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