PHOTOGRAMMETRIC DELINEATION ACCURACY OF LANDCOVER UNITS

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ABSTRACT:

The application of aerial photography for delineation of landscape and forest units is a common practise. The rectified delineated units are often used as input data for GIS layers. The registered delineation line in a GIS layer pretends accurate position of separation lines. Nevertheless it is known that this pretended accuracy is not reflecting reality while high uncertainty is implicated in the delineation itself. Subjective variations in interpretation of photographs heavily influence the delineation line. Objective of the investigation was therefore to examine the certainty of forest stand delineation based on infrared aerial photographs in scale 1:7000 and 1:20000. For the test series 10 interpreters had to delineate the same forest stands. The stand borders were separated into 3 different complexity classes, easy, medium and difficult. The attachment of the stand borders to the complexity class was based on a visual valuation of the complexity situation in the aerial photography. Within the defined testsites more than 50% of the stand borders were classified medium and less than 20% difficult. The persons incorporated in the tests proved all knowledge in forestry and photogrammetrie. The interpretation guidelines were reduced to substantial information on the characteristic features for stand classification and on basic delineation instructions. Because the accuracy of the used instrument Zeiss Planicomp P3 is very high , the influence of instrument inaccuracies on the delineation quality from aerial photographs were not taken into consideration. The results proved that the reliability of delineation is dependent on the complexity of the border line and on the scale of the photography. The cause of delineation variation was either due to different interpretation of the stand border or due to insecurities of the positioning of the delineation line while accepting the same stand border. The first cause needs more detailed interpretation criteria to address more agreement in the definition of stand units. The second cause is originated in psychophysical processes of perception what calls a different definition of the exact location of the borderline and can only be reduced with increasing experience of the interpreters.

KURZFASSUNG:

Die Verwendung von Luftbildern für die Abgrenzung verschiedener Landschafts- und Waldeinheiten ist weitverbreitet in der Praxis. Die abgegrenzten und geometrisch entzerrten Landschaftseinheiten werden vielfach als Eingangsdaten für die Weiterverarbeitung im GIS genutzt. Die im Rahmen der Photointerpretation erstellten Grenzlinien täuschen im GIS dann eine Genauigkeit vor, die durch das Aufnahmeverfahren nicht gewährleistet ist. Die subjektive Wahrnehmung beeinflußt den Abgrenzungsprozeß und führt zu einer gewissen Variation bei der Delinierung. Ziel der Untersuchungen war es diese Variationbreite zu untersuchen, um die Zuverlässigkeit bei der geometrischen Delinierung am Beispiel von Waldbeständen zu beschreiben. Für die Untersuchungen wurden Infrarotluftbilder im Maßstab 1:7000 und 1:20000 herangezogen. Die Testreihe wurde mit 10 Interpreten durchgeführt die alle die gleichen Waldbestände zu delinieren hatten. Die zu delinierenden Bestandesgrenzen wurden in drei Schwierigkeitsklassen eingeteilt, leicht, mittel und schwer. Die Zuordnung der Bestandesgrenzen zu den Schwierigkeitsklassen erfolgte über eine visuelle Einschätzung am Stereoskop. Die Interpreten hatten alle eine forstliche Ausbildung und Erfahrung im Bereich Photogrammetrie. Die Interpretationsanweisung war reduziert auf wesentliche Informationen zur Bestandesklassifizierung und zur Delinierung. Da die Genauigkeit des verwendeten Instrumentes Zeiss Planicomp P3 sehr hoch ist, wurden Ungenauigkeiten die durch das Instrument verursacht sind nicht berücksichtigt. Die Ergebnisse zeigten, daß die Zuverlässigkeit bei der Delinierung stark von der Komplexität der Grenzlinien und dem Bildmaßstab abhängt. Die Variationen in der Delinierung waren einerseits verursacht durch die unterschiedliche Auffassung der Interpreten über die Homogenität der abzugrenzenden Bestände, d.h. die Bildsituation wurde von den Interpreten unterschiedlich erfaßt und definiert, zum anderen durch die unterschiedliche Auffassung über die genaue Lage der Grenzlinienziehung, wobei hier alle Interpreten die selbe Bestandesgrenze erkannten und dieser folgten. Die Unsicherheiten in der Delinierung aufgund von unterschiedlichen Bestandesinterpretationen können durch ausführliche und präzise Interpretationsanweisungen verbessert werden. Der zweite Grund für die Ungenauigkeiten liegt im unterschiedlichen psychophysikalischen Wahrnehmungsvermögen der Interpreten sowie in Unsicherheiten bei der Meßmarkenführung und kann nur durch die Erfahrung der Interpreten minimiert werden.

1. INTRODUCTION

Along with environmental assessment the spatial inventorying and monitoring of areas is of high relevance. Basis for the spatial assessment of areas can either be maps, field data or remote sensing data. Within remote sensing data aerial photography is often used for the delineation and classification of landscape units. An important result of the delineation and classification of aerial photography is the production of maps. The delineation lines pretend then an accuracy which is not provided through the interpretation process. This is due to the fact, that the exact location of the delineation line is strongly dependent on the individual perceptibility of the interpreter, which is influenced by the experience and training background of that person.

Even so it is tried to make the interpretation process more objective by standardised interpretation keys, there remains a subjective influence on the delineation. In regard to the frequent use of aerial photographs for providing basic maps, it is of high interest to have an estimate how reliable the delineations are. First attempts to quantify the delineation accuracy in aerial photographs were provided by ZIHLAVNIK (1991), CONGALTON (1983), AKCA (1984) and GLEMSER (1993), but due the very few investigations there is still no clear idea on the influence of the definition accuracy on the certainty in delineation.. Objective of the investigation was therefore to quantify the reliability of an aerial photointerpretation. The investigation was concentrated on the delineation of forest stands.

2. BACKGROUND

In general there are three kinds of accuracy to differentiate (GLEMSER 1993):

- the digitising accuracy
- the discretion accuracy and
- the definition accuracy.

While the digitising and discretion accuracy are of small influence for the delineation accuracy the overriding inaccuracy is caused by the definition insecurities.

For the definition or recognition of an object it is of relevance that the object is in contrast to the surrounding and provides are certain systematic. In general the more clear the contours and the more simple the shapes the certainty of the delineation is increasing (SCHWIDEFSKY 1963). The shape psychology defines the following important rules which influence the delineation process:

- The tendency to continue lines in a straight forward or uniform way.
- The tendency to regard areas surrounded by closed lines as one unit.
- The tendency to produce simple and regular shaped elements.

Based on this it becomes clear that the delineation process is dependent on the individual perceptibility, but individual perceptibility will follow psychological rules which will provide for some objects a higher probability of consistent delineation than for others. A valuation of the certainty of delineation has therefore always take into account different complexity situations.

3. MATERIAL AND METHOD

3.1 Testsite and Material

The investigation was based on two sets of infrared aerial photographs in scale 1:20000 and 1:7000. One testsite was located south-west of Germany and belongs to the forest district Backnang. The forest district Backnang covers mainly state forest and is characterised by spruce (picea abies) and beech (fagus sylvatica) stands. The silviculture system is the age class forest with a maximum in the younger age classes. The photogrammetric measurements and photointerpretation were carried out with the analytical plotter ZEISS PLANICOMP P3 based on infrared aerial photographs with the following specifications:

- flight date: 30. July 1992
- flight direction: north-south
- photo scale: 1:7000
- film type: Kodak Aerochrome Infrared 2443
- Camera type: metric camera Zeiss 23x23 cm
- object lens 300 mm

The other testsite was located south-east of Rome. This more complex forest area belongs with 70% to the community and with 30% to private people. The dominating silviculture system is the coppice forest with transitions into high forest. The forest is dominated by broadleaf trees of different species. The photogrammetric measurements and the photointerpretation was also carried out with the analytical plotter ZEISS PLANICOMP P3 based on infrared aerial photographs with the following specifications:

- flight date: 12.September 1991
- fight direction: north-south
- photo scale: 1:19000 to 1:24000
- film type: Kodak Aerochrome Infrared 2443
- camera type: Wild RC 20
- object lens: 150 mm.

After the photogrammetric measurements for further evaluation the data were transferred into ARC/INFO 3.4D GIS and statistical analysed with EXCEL 5.0.

3.2 Method of evaluation

As already mentioned the certainty of a delineation is dependent on three factors:

- the technical frame
- the complexity of the area and
- the subjectivity of the interpreter.

It is clear that the technical performance of the today's instruments is of such a quality that this is not the limiting factor for the certainty of a delineation based on aerial photographs, while the human influence together with the complexity of the area has an decisive influence on the delineation result. Because the ability of interpreters to perform a clear and consistent delineation of forest units is strongly dependent on the apparently of the border lines, a valuation has to be based on different degrees of area complexity. In the frame of this investigation three categories of border line complexity were established:

- easy: all sharp lines; simple geometric shapes; good visibility in the stereo model

- medium: borders clearly visible but not obvious; only small but still distinct differences to the neighbour stand; reduced visibility in the stereo model e.g. edge of the photo.
- Difficult: no clear border lines; no obvious difference to the neighbour stand; bad visibility in the stereo model e.g. hidden position due to exposition.

3.3 Selection of the test objects

For the testsite in Germany 5 stereo models, which is 25% of all existing stereo models have been selected randomly. Within the 5 stereo models all border lines of the different forest units have been visually classified into one of the three different complexity classes.

For the Italian testsite a stratified sampling was necessary, due to the fact that the area is very inhomogeneous. Therefore three geomorphologic units were first delineated and then in each subunit the samples randomly selected. One subunit was represented by 2 stereo models, while each of the other two subunits were represented by 3 stereo models. The total of 8 stereo models was again 25% of all existing stereo models. The border lines of all forest units in the selected stereo models were again visually classified into one of the three complexity classes.

3.4 Delineation procedure

In order to value the delineation accuracy 10 testpersons were selected which provided the same education background and had all basic photogrammetric knowledge. Five persons even had an extensive experience in aerial photointerpretation and photogrammetric measurement. To achieve standardisation for the delineation an interpretation key was developed to provide information on

- the subject of delineation
- the photomaterial
- the test area
- the stands which had to be delineated
- the rules of delineation and
- the successive steps for interpretation

Important for the comparative valuation of the delineation results were the rules for the delineation. The rules comprised for both testsites the following points:

- the stands had to be delineated according to their homogeneity in tree species and age,
- the delineation line between unequal high stands or between forest and non forest had to be located in the centre of tree crowns of the higher stands,
- for equal high stands the delineation line had to be located in the centre of the deepest visible point between these stands,
- discontinuities had to be taken into consideration for areas with more than 30 m width (approximately two tree crowns,
- in case only tree species are changing areas with more than 60 m width or at least one hectare size had to be taken into consideration.

For the interpreters it was not necessary to identify the type of tree species but they only had to register the change in tree species. Aside to the stereo model each interpreter had a paper copy of the infrared airphoto, where all stands which had to be delineated were marked by numbers. Each interpreter had to delineate the same stand twice. During the process of delineating the interpreter was able to see his delineation in the stereo model through the VIDEOMAP device.

3.5 Calculation of the delineation accuracy

Due to the assumption that all delineated lines represent equally the truth, there is no 'true line' to which the test delineations can be referred. On the other hand this means that all lines represent a certain inaccuracy. In order to quantify this inaccuracy all delineation lines were first transferred into ARC/INFO GIS and reduced to x and y co-ordinates. Due to the deviation between the delineation of different interpreter the stand border was then represented by a net of two-dimensional lines. After the lines were framed by a minimum and a maximum polygon a measure of the variation width was possible. For the calculation of the delineation variation subsets out of the polygons in form of polygon pieces were selected representing equally each complexity class. In order to quantify the variation of all delineations each selected polygon piece was buffered starting one time from the maximum polygon piece and second time from the minimum polygon piece. The buffers were step by step enlarged till all existing delineation lines in that polygon piece were included. For each buffer step around the maximum polygon respectively around the minimum polygon the length of delineation lines included was calculated. This calculation provided a distribution of line length starting from the minimum respectively maximum polygon piece. It was then assumed that the buffer section with the highest density of lines, respectively the section with the in total longest line distance, is the buffer section with the highest probability to represent the true stand border line. After the distribution was then transformed in that way that the buffer section with the maximum length of lines was the reference the demonstration and calculation of
line length over distribution width (buffer section) became possible.

4. RESULTS

All together 36763 m delineated stand border was evaluated. 63.7% of the border lines were classified 'easy', 20.3% were classified 'medium' and 16% were classified 'difficult'.

4.1 Evaluation of the 1:7000 aerial photographs

All together 7169 m of stand border was delineated in the large scale photographs. Table 1 gives the distribution over the different complexity classes.

Tab.1: Evaluated border length in each complexity class (scale 1:7000)

Complex class	testarea 1	testarea 2	testarea 3	total
easy	1168 m	976 m		2144 m
medium	693 m	1170 m	596 m	2432 m
difficult	968 m	626 m	999 m	2593 m

The investigation shows for the complexity class 'easy' 80% of the delineation lines within 2 m distance and 100% within 5 m (Fig. 1). For the complexity class 'medium' 100% of the delineation lines are included within 20 m, but already 59% of the lines are included within 5 m and 91% within 11 m. (Fig. 1). For the complexity class 'difficult' all delineations are within 57 m (100%), but already 99% are within 41 m, 90% are within 27 m and 60% of all lines are within 12 m (Fig.1). The wide distribution of lines for the 100% in the complexity class 'difficult' points towards the fact that with increasing complexity of the stand border the probability for single break outs is growing.

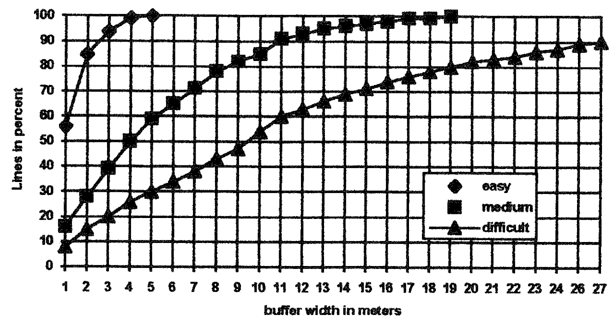

Fig. 1: Distribution of the delineation differentiated in three complexity classes (evaluation based on aerial photograph 1:7000)

Evaluation of the 1:20000 aerial photographs

All together 15063 m border line were included in the evaluation on testsite 2. The distribution over the complexity classes is provided in table 2.

Tab.2: Evaluated border length in each complexity class (scale 1:20000)

complex class	testarea 1	testarea 2	total
easy	4680 m	1451 m	6131 m
medium	2563 m	2161 m	4208 m
difficult	2997 m	1211 m	4208 m

The distribution in the complexity class 'easy' showed for all delineations (100%) a maximum spread of 18 m, but already 90% of the lines were located within 10 m (Fig.2). For the complexity class 'medium' all delineations were located within 38 m and 90% of the lines were located within 24 m (Fig.2). For the complexity class 'difficult' all delineations distribute within 80 m, 90 % of all lines are located within 46 m and 60% of all lines distribute within 22 m (Fig.2). The result for the complexity class 'difficult' shows similar to the large scale photographs the tendency to have single breakouts, which produce a large distribution for 100% of the delineation lines.

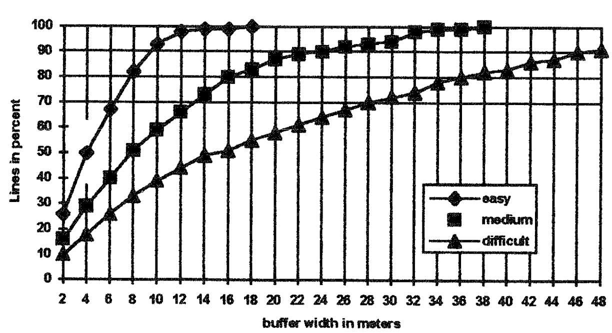

Fig.2: Distribution of the delineation differentiated in three complexity classes (evaluation based on aerial photographs 1:20000)

The tables 3,4 and 5 give a summary of the proportion of delineation lines in each distribution class (buffer step) for the 1:7000 and the 1:20000 scale.

Tab. 3: Distribution of all delineation lines for the aerial photographs 1:7000

distribution width	proportion of lines
1 m	41.2%
2 m	62.1%
3 m	71.3%
4 m	77.8%
5 m	80.6%
6 m	82.6%
7 m	84.4%
8 m	86.4%
9 m	88.1%
10 m	89.6%
11 m	91.4%
56 m	100%

Tab. 4: Distribution of all delineation lines for the aerial photographs 1:20000

distribution width	proportion of lines
2 m	20.4%
4 m	38.4%
6 m	52.7%
8 m	65.3%
10 m	74.6%
12 m	80.4%
14 m	83.4%
16 m	85.4%
18 m	87.3%
20 m	88.8%
22 m	90.9%
78 m	100%

Tab. 5: Distribution of 90% of all lines differentiated in complexity classes

complex class	accuracy in the field	accuracy in the field	model accuracy	model accuracy
	1:7000	1:20000	1:7000	1:20000
easy	3 m	10 m	0.4 mm	0.5 mm
medium	11 m	24 m	1.6 mm	1.2 mm
difficult	27 m	46 m	3.8 mm	2.3 mm

In the frame of this investigation two different types of influence on the delineation accuracy were to observe.

1. Variations due to a different definition opinion of the interpreter about what is homogenous and what belongs to what unit. The more complex the stand situation was the more heterogeneous was the association to stand units.

2. Variations due to a different positioning of the exact border line. In this case all interpreter defined the same border but positioned the delineation line along this border not exact at the same place. The reasons for this inaccuracy are on one hand a different perception of the border line by the interpreter and on the other hand insecurities in fixing the floating mark and positioning the polygon points.

5. CONCLUSIONS

In order to improve the delineation accuracy respectively reduce the variation width it is of high relevance to have detailed and standardised interpretation keys. In addition to that it is important to have experienced interpreters to reduce insecurities in positioning the floating mark and polygon points. Nevertheless a certain variation will persist because some border lines are flowing and cannot be fixed to a distinct line as well as the individual perceptibility of the interpreters can never be totally homogenised. One possibility to take care of the persisting variations is the definition of bands of same probability instead of lines. But in order to implement this in the frame of a GIS a high number of investigations would be needed to take in consideration the influence of photo scale and complexity.

6. LITERATURE

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