SIMPLE PHOTOGRAMMETRIC METHODS
FOR REGISTRATION OF RURAL LAND IN AFRICAN COUNTRIES

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ABSTRACT

Registration of extensive rural area in the African countries would take many years with the traditional surveying methods. Since the major motives for registration of rural land are providing the title to land, identification of occupied land and facilities of the rural development, mapping for these purposes can be done with less rigorous standards. In this paper the remarks are given on the possibility of the use of the photographic maps and aerial mosaics in order to register the land of the rural areas in the African countries.

1. INTRODUCTION

Cadastral surveys of the enormous extensive rural areas in the African countries with the traditional surveying methods are very expensive and would take a long time. In most of these countries there is no systematic approach to cadastral surveys. They are mostly carried out as ground surveys using the traditional surveying methods. Though the present law makes a provision for the use of some photogrammetric methods for the purpose of cadastral surveys, but so far they have only been used to a very limited extent. The reason being is the high accuracies stipulated in the Land Survey Regulations, which suggest the use of only complicated and time-consuming photogrammetric methods. These approaches are much too expensive and complex to be attractive. This is one of the reasons for the delay in the common use of the photogrammetric methods in cadastral surveying.

The major motives for mapping land occupancy in the rural land are:
- to provide title to land;
- to identify occupied land;
- to facilitate rural development.
Mapping for these purposes can be compiled with less rigorous standards of accuracy. However, the results of cadastral surveys have to be up-to-date. Even the most precise and sophisticated data have a limited value if they do not depict the actual situation. The above suggests a rapidly produced and relatively inexpensive survey by using methods which are not beyond the resources of the country. The use of photographic maps, such as an ortho-photo map or maybe even uncontrolled airphoto mosaics seems to be a useful tool to meet the needs of cadastral surveying of the extensive rural areas. In some African countries there were occasional attempts to use for these purposes the control and uncontrolled mosaics. However, the law does not provide for such methods and if they are to be used some amendments will be required. The lack of system of cadastral mapping in the rural areas in the African countries needs the urgency and complexity of the problem to be solved. There is no time for slow and complex mapping procedures. The use of the orthophoto map and/or airphoto mosaics could solve that problem significantly.

2. PHOTOGRAPHIC MAPS AND AIRPHOTO MOSAICS FOR CADASTRAL SURVEYS OF THE RURAL AREAS

The photographic picture of the terrain provides maps with an excellent background with an infinite number of details in their natural appearance and distribution. The objects are recognised by their pictorial qualities. The type and pattern of cultivated land and its general use, as well as desert and marsh areas can be easily identified. Location of property boundaries and other details to be determined can be referred to natural features of the terrain, such as grass clumps, small bushes, drainage patterns, and many other planimetric details which can be readily recognised on the photographic map. This is very important in cases where it is not possible to target many points in the field.

An orthophoto map, which has the metric qualities of a map and all the details are depicted in their natural appearance and their true dimensions, is commonly used in many applications. Since the production of orthophotos is a fast and partly or fully automated process which simultaneously supplies information on contour lines and a numerical presentation of terrain, then this technique offers high flexibility for rapid and economical mapping.

In some countries, mainly in the South American region, an orthophoto technique has been already adopted for establishment of a country land inventory. This method seems also to become the future approach for land inventory of the extensive rural areas in the African countries.

The simpler approach is an uncontrolled mosaic where the aerial photographs are enlarged only with an ordinary reproduction camera to the approximated scale on the basis of some known distances. Since the photograph is not differentially rectified but only enlarged, the scale is not uniform regarding the tilt of photo and the relief of terrain. Corrections of scale due to tilt of the photograph can be introduced by using the simple analytical transformation after digitizing the required content of the enlarged photograph. Influence of relief of terrain cannot be eliminated in such an easy way, so this approach could only be used where the terrain has a moderate relief.

3. DESCRIPTION OF THE EXPERIMENT

In 1986, the pilot project was carried out in the Land Surveying Section at the University of Zambia using the enlarged photographs for Cadastral Surveys of the rural area (1). In 1987 the next project was extended to the larger area(3). There were a few other projects which had been carried out earlier in the Survey Department in Lusaka, Zambia, to evaluate usefulness of the conventional photogrammetric methods for the cadastral surveys (4), (5). In 1968, terrain consisting of ten farms with the area of 8000 ha was photographed at scale 1:10 000. The positions of the premarked points which had been determined by traversing method were compared with the results obtained by the semi-analytical aerotriangulation method. Maximum differences in X and Y were 0.4m and 0.5m respectively. Average and maximum differences in distances of lengths about 400m between two points obtained by both methods were $\pm$0.26m and 0.54m, respectively. In 1981, the area of 18 000 ha was photographed at scale 1:20 000. All boundary beacons had been premarked and their positions in X and Y were determined by semi-analytical aerotriangulation with an average residual

error of ±0.4m.   In 1983, the terrain consisted of fifty farms with the area of 6 000 ha photographed at scale 1:20 000.   Premarked beacons were obtained by the aerotriangulation method.   For checking purposes, six boundary distances with average length of 300m were measured on the ground. The results showed an average difference of ±0.2m.   A new test survey consisting of 105 parcels of land of over 1 300 ha was started in 1985.   The area is intended to be photographed at two scales: 1:20 000 and 1:15 000, with different types of premarked points.   Part of the area was to be surveyed using conventional methods for comparison purposes.   The main conclusions which have been drawn from these experiments are as follows:
- for a block containing a large number of properties (where boundary lengths are in excess of 150m) the photogrammetric method provided results of adequate accuracy;
- since premarked beacons must be visible, clearing the area around them has to be carefully considered.   In heavy bush areas photogrammetry is not recommended.

The pilot project which has been based on the enlarged photographs covered the area of 1 800 ha in Chalimbana Village near Lusaka, with the moderate relief of ±20m around the photograph.   The actual photographs at scale 1:30 000, which is the common scale for the basic map in Zambia, were enlarged to an approximate scale of 1:5 000 on the basis of two distances known from the field measurements.   All boundaries and boundary corners, were identified and marked on the mosaic and targeted by the wooden pegs on the ground.   The study area consisted of 28 land parcels owned by 18 farm-tenants.   During the field work all the land parcels were numbered and the names of tenants and relevant agricultural data were collected. The field control points and boundary points were measured by the traversing and the polar methods, respectively.   Since, for the purpose of comparison, the stereoplotting method has also been used, the heights of the control points were determined by the trigonometric levelling.   The X and Y coordinates of four control points and all boundary points were measured on the mosaic with the rectangular coordinatograph.   The coordinates of the same points were also obtained with the stereoplotter A-8.   Since the scale of the mosaic was not uniform, the affine transformation has been applied to transform the mosaic coordinate system to field coordinate system.   Differences in X and Y coordinates of boundary points obtained by the field and mosaic methods and the stereoplotting and mosaic methods are shown in Table 1, columns 2 and 3 and columns 4 and 5, respectively.   The main square errors are: $m_X = \pm0.46$m, $m_y = \pm0.41$m for a comparison of the field and the mosaic methods and $m_X = \pm46$m, $m_y = \pm0.32$m for the stereoplotting and mosaics methods.   On the top of it areas of 26 parcels were measured with a planimeter from the maps obtained by stereoplotting and mosaic methods.   The differences between corresponding areas are shown in Table 1, column 7.   The differences are also expressed as a percentage of the measured area (column 8).   The average error in areas is ±5.4m^2 or $\pm1.8\%$ of the measured area.   The results which have been obtained in this pilot project showed that for the terrain with a moderate relief the use of the uncontrolled mosaic can be taken into consideration for the cadastral surveys of the extensive rural areas.   However, to obtain tolerable accuracy of boundary corners, say ±0.5m, the measured mosaic coordinates should be transformed to the field system by the projective or affine transformation on the basis of four horizontal control points for each photograph.   These points can be determined by the aerotriangulation method.   Identification of the boundary corners on the aerial enlarged photographs is a very important stage and has to be done

TABLE 1

RESULTS OF MEASUREMENT OF THE BOUNDARY CORNERS AND AREAS OF THE PARCELS

No. of Boundary	Differences between Field and Mosaic Points' Coordinates		Differences between Stereoplotting & Mosaic Points' Coordinates		No. of Parcels	Differences in Areas Obtained from Stereo-Plotting & Mosaic Map	
	$dx_{(m)}$	$dy_{(m)}$	$dx_{(m)}$	$dy_{(m)}$		$dA = A_s - A_m$ (m^2)	$\dfrac{dA}{A}$ (in%)
1	2	3	4	5	6	7	8
1			-0.69	0.53	2	2	0.6
2	-0.29	0.67	-0.48	0.50	3	0	0.0
3			-0.46	0.51	4	4	3.5
4	0.42	0.46	0.53	0.26	5	2	2.3
5.	0.19	0.23	0.33	0.02	6	2	0.7
6	0.20	0.66	0.38	0.48	7	2	0.6
7	-0.06	0.36	-0.83	0.37	8	4	2.2
8	0.19	0.33	-0.83	0.34	9	6	2.3
9	-0.96	0.42	-0.36	0.22	11	0	0.0
10			-0.41	0.16	12	2	3.4
11			-0.28	0.37	13	0	0.0
12			-0.34	0.47	14	6	3.8
13			-0.46	0.28	15	2	4.6
14			0.43	0.13	16	2	4.2
15	-0.92	0.11	-0.39	0.00	17	4	0.7
16			0.36	0.35	18	10	2.1
17			-0.40	0.11	19	6	2.3
18			0.47	0.61	20	18	1.6
19			-0.44	0.19	21	6	1.0
20	-0.27	0.40	-0.40	-0.22	22	4	1.9
21	-0.55	0.70	-0.46	0.22	23	4	1.2

TABLE 1 Cont'd

RESULTS OF MEASUREMENT OF THE BOUNDARY CORNERS AND AREAS OF THE PARCELS

No. of Boundary	Differences between Field and Mosaic Points'Coordinates		Differences between Stereoplotting & Mosaic Points' Coordinates		No. of Parcels	Differences in Areas Obtained from Stereo-Plotting & Mosaic Map	
	$dx_{(m)}$	$dy_{(m)}$	$dx_{(m)}$	$dy_{(m)}$		$dA=A_s-A_m$ (m^2)	$\frac{dA}{A}$ (in %)
1	2	3	4	5	6	7	8
22	-0.27	-0.32	-0.32	-0.20	24	2	0.4
23	0.43	0.23	0.47	0.33	25	6	3.6
24	-0.50	0.24	-0.34	0.17	26	24	2.2
25			-0.39	0.23	27	4	0.3
26	-0.62	-0.52	-0.46	-0.40	28	2	0.4
27	0.32	0.42	0.32	0.42			
28			0.35	0.48			
29	-0.36	-0.56	-0.47	0.09			
30	0.50	-0.50	0.35	-0.38			
31	-0.52	-0.34	-0.64	-0.26			
32	-0.37	-0.29	-0.44	-0.20			
33			-0.08	-0.43			
34			-0.47	-0.22			
35	0.43	-0.25	0.43	-0.25			
36			-0.26	-0.40			
37			-0.36	-0.07			
38			-0.38	-0.17			
39	0.08	-0.34	0.18	-0.50			

in the field very carefully. It is obvious that the photographs used for the cadastral surveys must be up-to-date and should be taken at the time of minimum vegetation. In heave bush areas the beacons have to be premarked and clearing the area around such beacons must be carefully carried out. Premarking must preceed aerial photography by

as little margin of time as possible in order to avoid destruction of marks either by lapse of time or by any human activity in the area.

4. CONCLUSIONS

The need for creation of the Land Data System calls for simplification of cadastral surveys.   In the enormous rural areas the conventional survey methods cannot deal with the huge amount of cadastral works. The simpler and quicker methods are needed.   In selecting the most suitable survey method such factors must be considered as: cost and viability of a survey, topography, size and location of terrain, distribution and size of parcels, existing land use and availability of existing survey data.   Due to the above factors the approach should therefore be flexible.

The photographic maps, with their continuous tone imagery of the ground which gives a large number of details to be identified, are adequate for land inventory.   An orthophoto method is obviously the superior and the most common for obtaining these photographic maps.   The speed, efficiency and accuracy with which planimetric features can be obtained in the mapping process, are the accelerating factors which make an orthophoto method so attractive.   However, in some cases when the orthophoto systems are not available and the terrain has a moderate relief the simpler approach of the aerial mosaics could be also taken into consideration.   In this case, however, the required details of the separated enlarged photographs should be digitized and transformed to the field coordinates system.

Finally, it is worth noting that in the near future, the orthophoto method is assumed to be put to test in cadastral surveys of the rural areas in some African countries.

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