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Orthomosaics of Historical Aerial Photographs and Horizontal Accuracy Analysis

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I. Introduction

- Research Background
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Research Background and Objective

- One of grand challenges in terms of land use dynamics is to understand anthropogenic landscape
- Historical aerial photos are one of important data to understand historical landscape
- However, there are several issues to handle historical air photos

Problems	Possible solutions
P1. Data accessibility of historical data	S1. UConn Magic provides air photos (1934~)
P2. Not georectified and fragmented images	S2. Build an orthomosaic
P3. insufficient information to align and calibrate photos	S3. Use supplementary data (e.g. ground control point; GCP)
P4. Low image quality due to scanned data	S4. Select high-quality image among data for orthomosaicking procedure

Research Background and Objective

- In this context, this study aims
  1) To propose a method for the automated orthomosaicking of historical aerial photographs
  2) To analyze the horizontal accuracy of these outputs by comparing outputs of 1934 and 1951

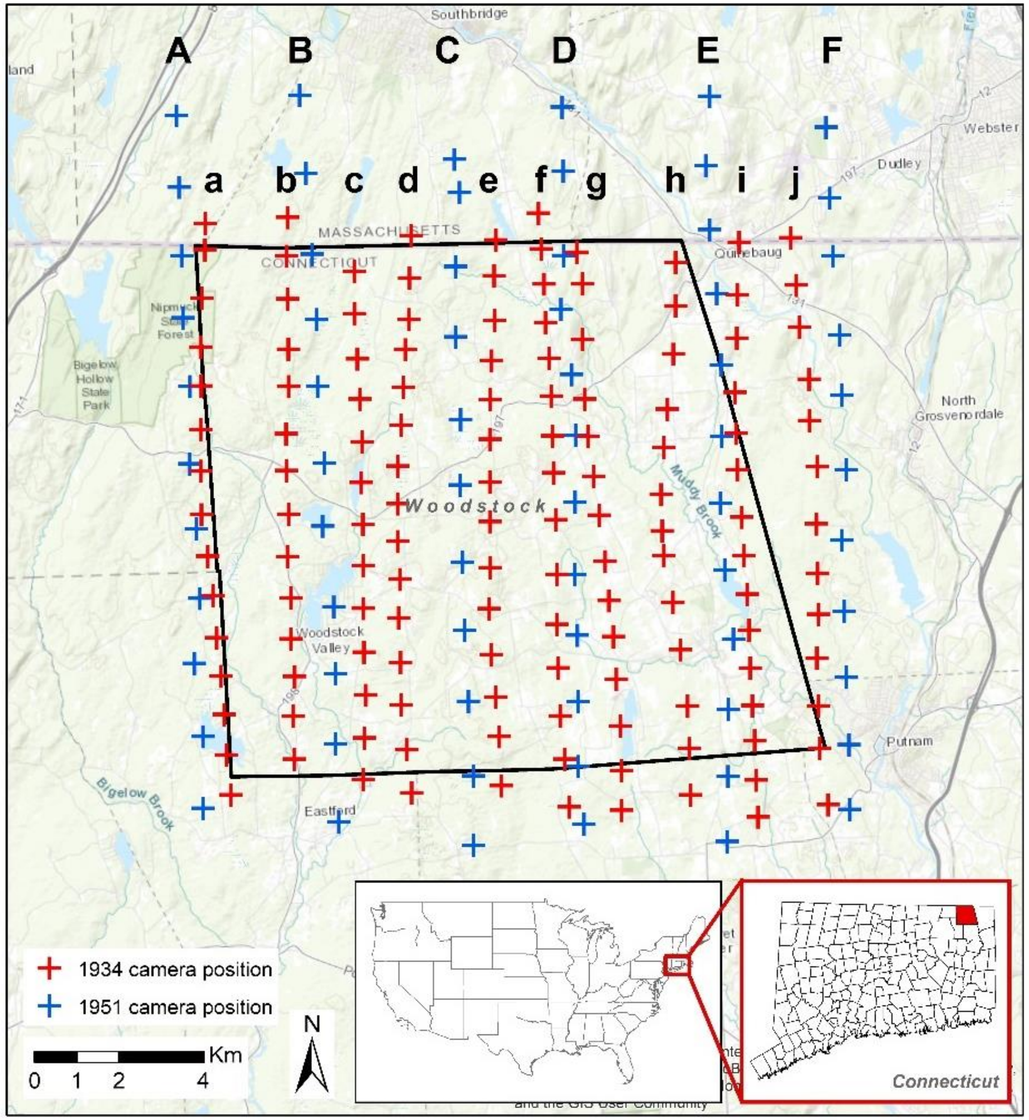
- In particular, specific research questions include
  1) How to build an orthomosaic from historical non-georectified air photos?
  2) How to assess horizontal accuracy of orthophotos?
  3) What factors affect the quality of orthomosaic?

II. Data and Method

- Study Area
- Data
- Method

Study Area

- Woodstock town, CT, USA (159 km^2)
- 141 images for 1934
- 68 images for 1951



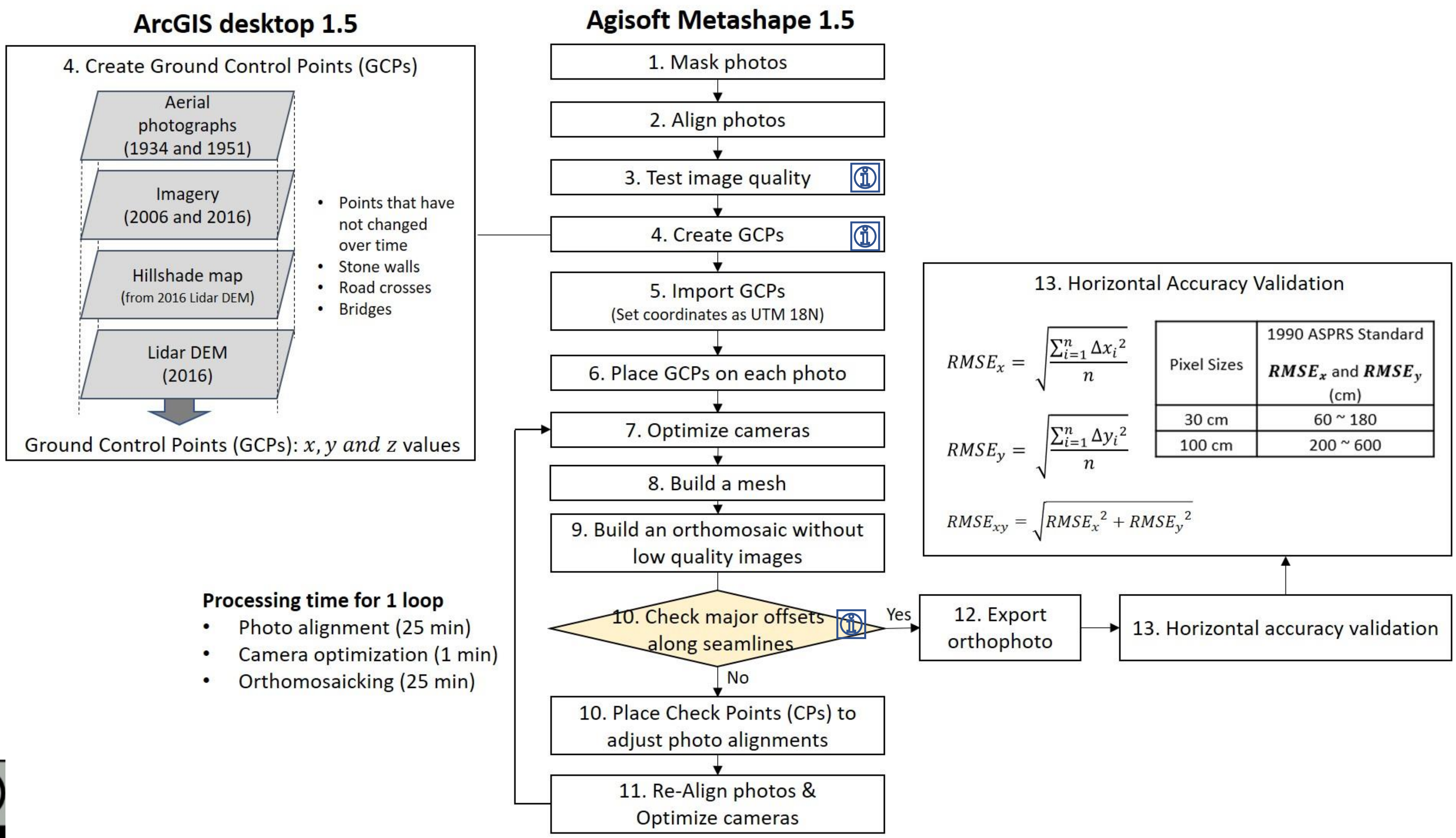
The map of study area and distribution of aerial photos for 1934 and 1951

Data

Data	Year	Resolution (map scale)	The number of photographs (area)	Sources	Note
Aerial photographs (Black and White)	1934	0.3 m (1:12,000)	141 (264 Km^2)	UConn Air Photo Archive[1]	Photos taken in 1934 April
	1951	0.9 m (1:20,000)	68 (380 Km^2)		09/05/1951, 10/13/1951, 11/25/1951, and 11/27/1951
Ortho-photographs	2006	1 m	-	CTECO[2]	Reference data for Ground Control Points (GCPs)
	2016	0.07 m	-	NAIP[3]	
Digital Elevation Model (DEM)	2016	1 m	-	CTECO	
Hillshade Image	2016	1 m	-	2016 DEM	

[1] https://connecticut.maps.arcgis.com/apps/View/index.html?appid=044e8e6266aa44dc8ccc9b6e2eecacb4
[2] Connecticut Environmental Conditions Online
[3] National Agriculture Imagery Program

Method



Processing time for 1 loop

- Photo alignment (25 min)
- Camera optimization (1 min)
- Orthomosaicking (25 min)

Method

Step 3. Test image quality

- Image quality can be estimated based on **sharpness** of image (0 < Image quality < 1) (Agisoft LLC, 2019)
- Estimated image quality
  - 1934: 0.47 to 0.66 (Note: image less than 0.5 not used for orthomosaiciking step)
  - 1951: 0.78 to 0.84

↑ The lowest image quality (1934)

↑ The highest image quality (1934)

Method

Step 4. Create GCPs

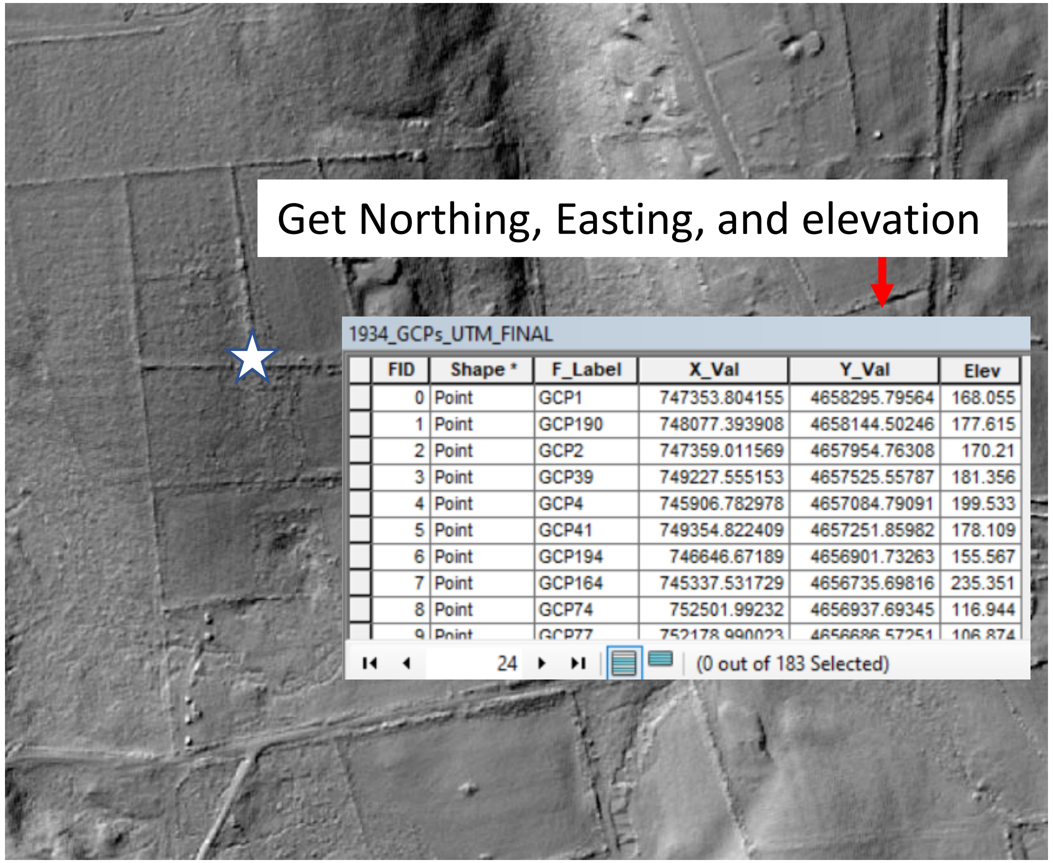
Priority:

1) Stonewall
2) Road (intersection or edge)
3) Fixed structures (i.g. bridge, dam, etc.)
4) Natural landscape (i.g. creek intersection)

1934 Aerial photos

VS.

Hillshade or orthophotos

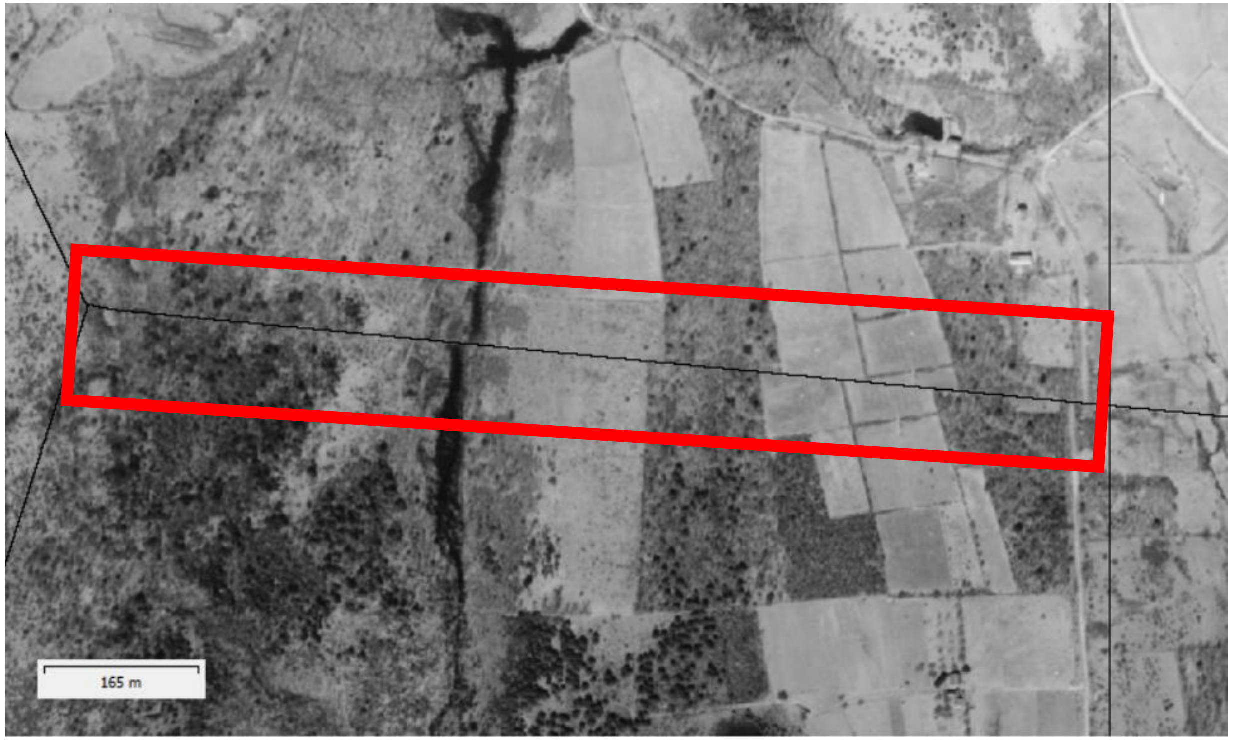


FID	Shape *	F_Label	X_Val	Y_Val	Elev
0	Point	GCP1	747353.804155	4658295.79564	168.055
1	Point	GCP190	748077.393908	4658144.50246	177.615
2	Point	GCP2	747359.011569	4657954.76308	170.21
3	Point	GCP39	749227.555153	4657525.55787	181.356
4	Point	GCP4	745906.782978	4657084.79091	199.533
5	Point	GCP41	749354.822409	4657251.85982	178.109
6	Point	GCP194	746646.67189	4656901.73263	155.567
7	Point	GCP164	745337.531729	4656735.69816	235.351
8	Point	GCP74	752501.99232	4656937.69345	116.944
9	Point	GCP77	752178.990023	4656686.57251	106.874

Method

Step 10. Check the quality of orthomosaic

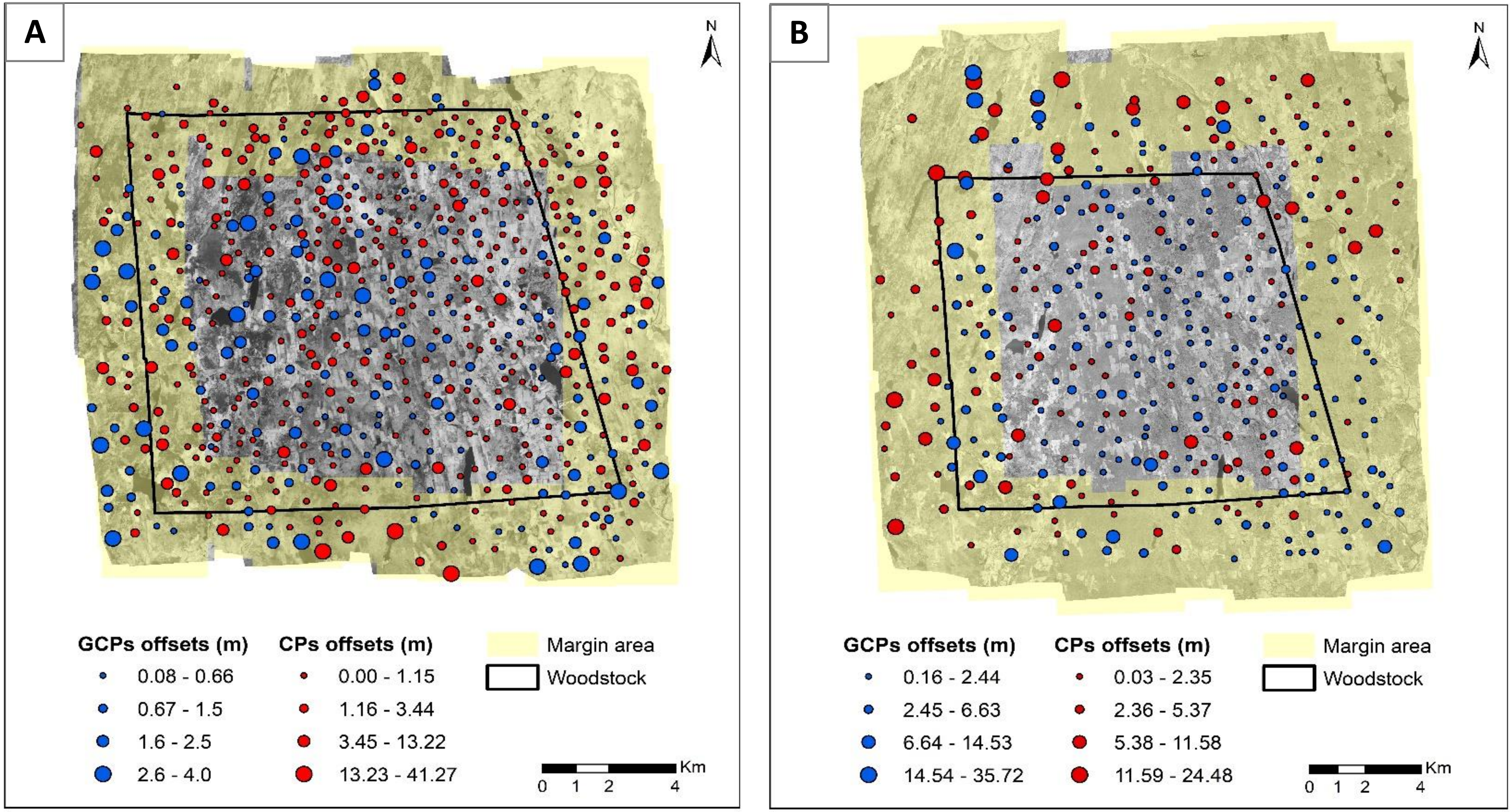
Good



Bad (15m offset)

III. Result

The Results of 1934 and 1951 Orthomosaics with Offsets



The results of orthomosaics and distribution of offsets (A: 1934; B: 1951)

The Results of Horizontal Accuracy Assessment

The horizontal accuracy results from 1934 and 1951 orthomosaics

	1934		1951	
	GCPs	CPs	GCPs	CPs
Count	219	446	235	167
$\mathbf{RMSE_x}$ **(m)**	1.06	0.89	3.42	3.71
$\mathbf{RMSE_y}$ **(m)**	0.92	0.87	2.85	3.58
$\mathbf{RMSE_{xy}}$ **(m)**	**1.40**	**1.24**	**4.45**	**5.16**
1990 ASPRS $\mathbf{RMSE_{xy}}$ **(m)**	**0.6~1.8**		**2.0~6.0**	

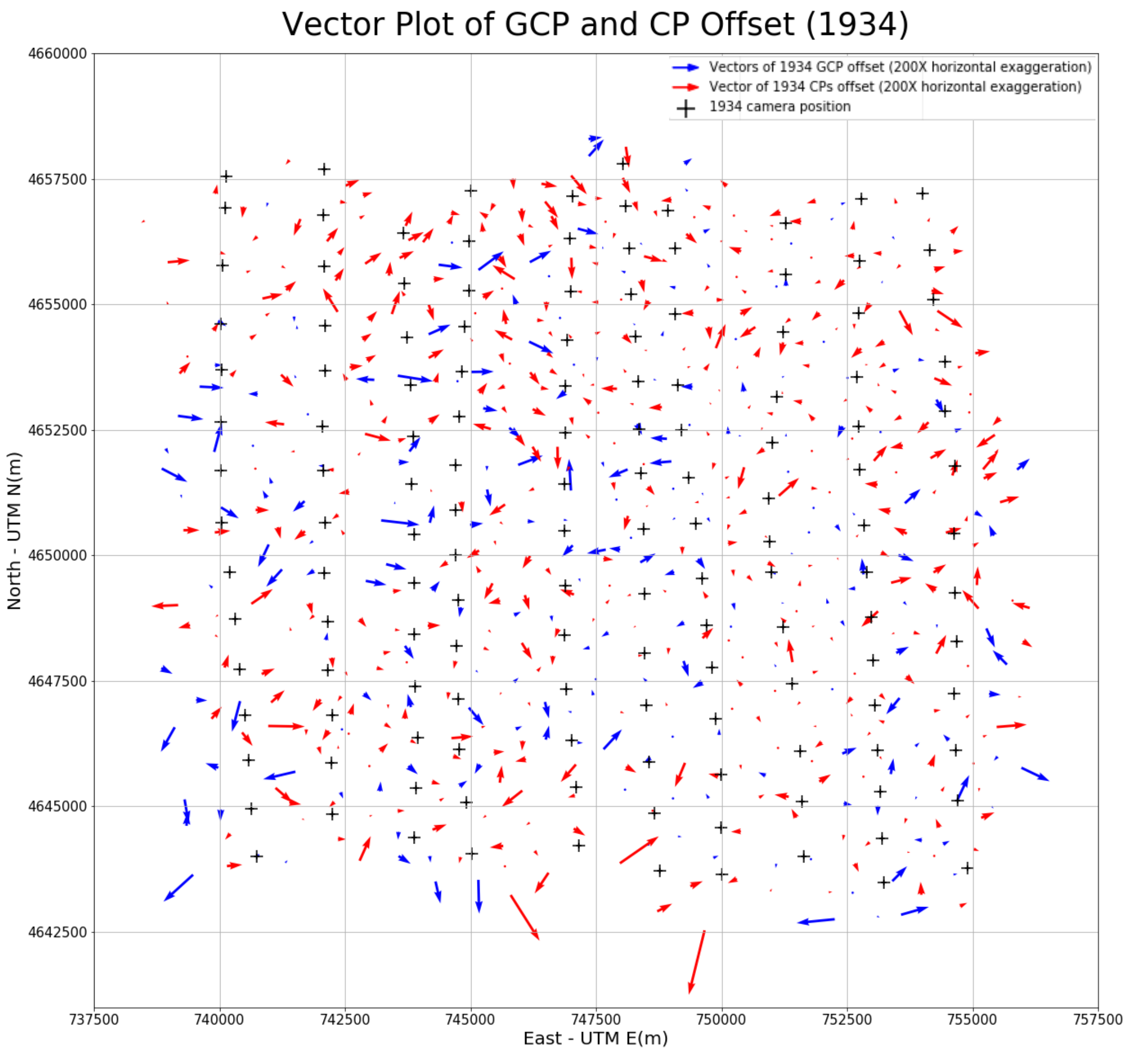
The Comparison of GCPs and CPs Offsets between Margin and Inside Area

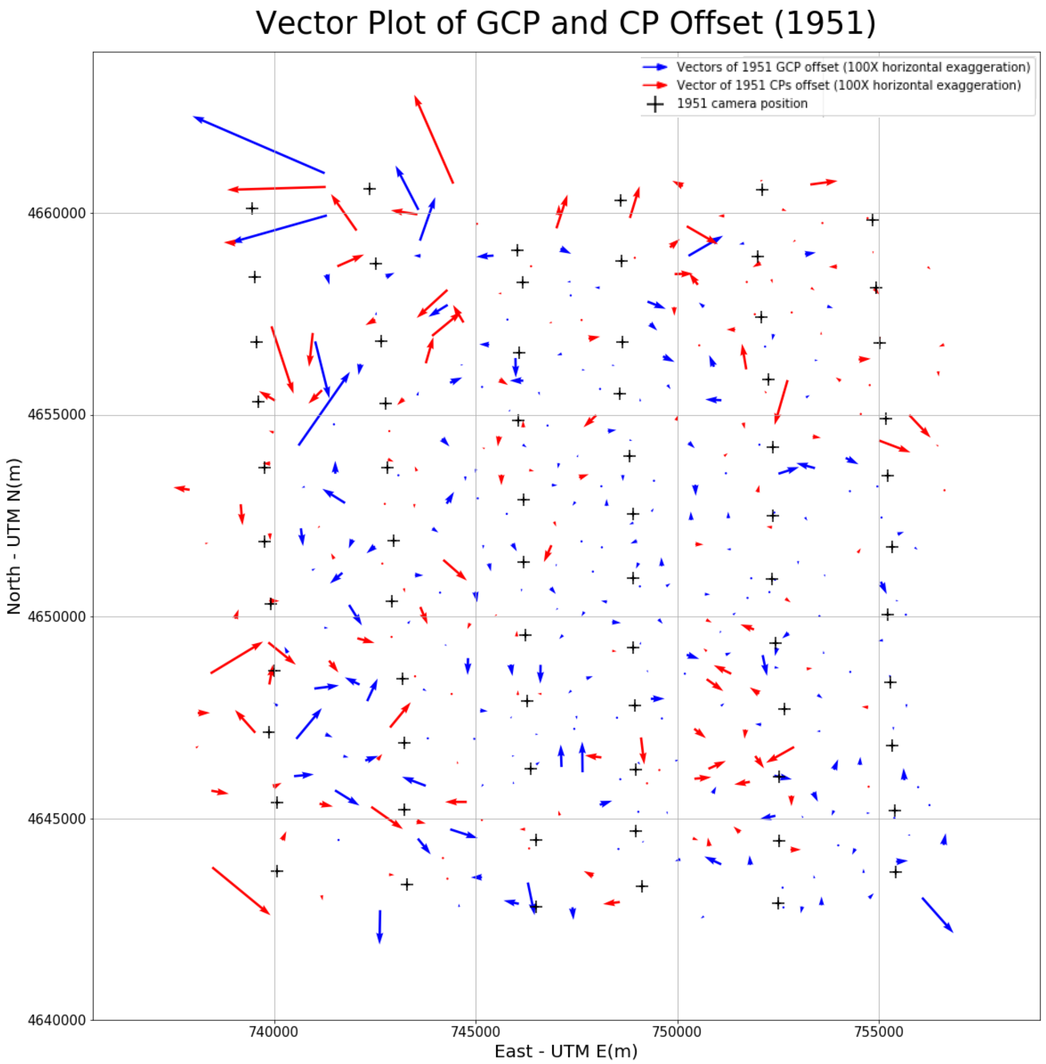
The statistics of GCPs and CPs offset from different areas (margin area and inside area)

	1934						1951					
	GCPs			CPs			GCPs			CPs		
	Count	Mean offset (m)	Std.	Count	Mean offset (m)	Std.	Count	Mean offset (m)	Std.	Count	Mean offset (m)	Std.
Margin area	116	**1.20**	0.97	230	**1.67**	1.41	45	**4.12**	6.68	52	**4.95**	5.80
Inside area	103	0.96	0.82	216	0.92	1.20	190	2.04	2.45	115	2.60	2.44
Total	219	1.08	0.90	446	1.31	1.24	235	2.44	3.73	167	3.33	3.96

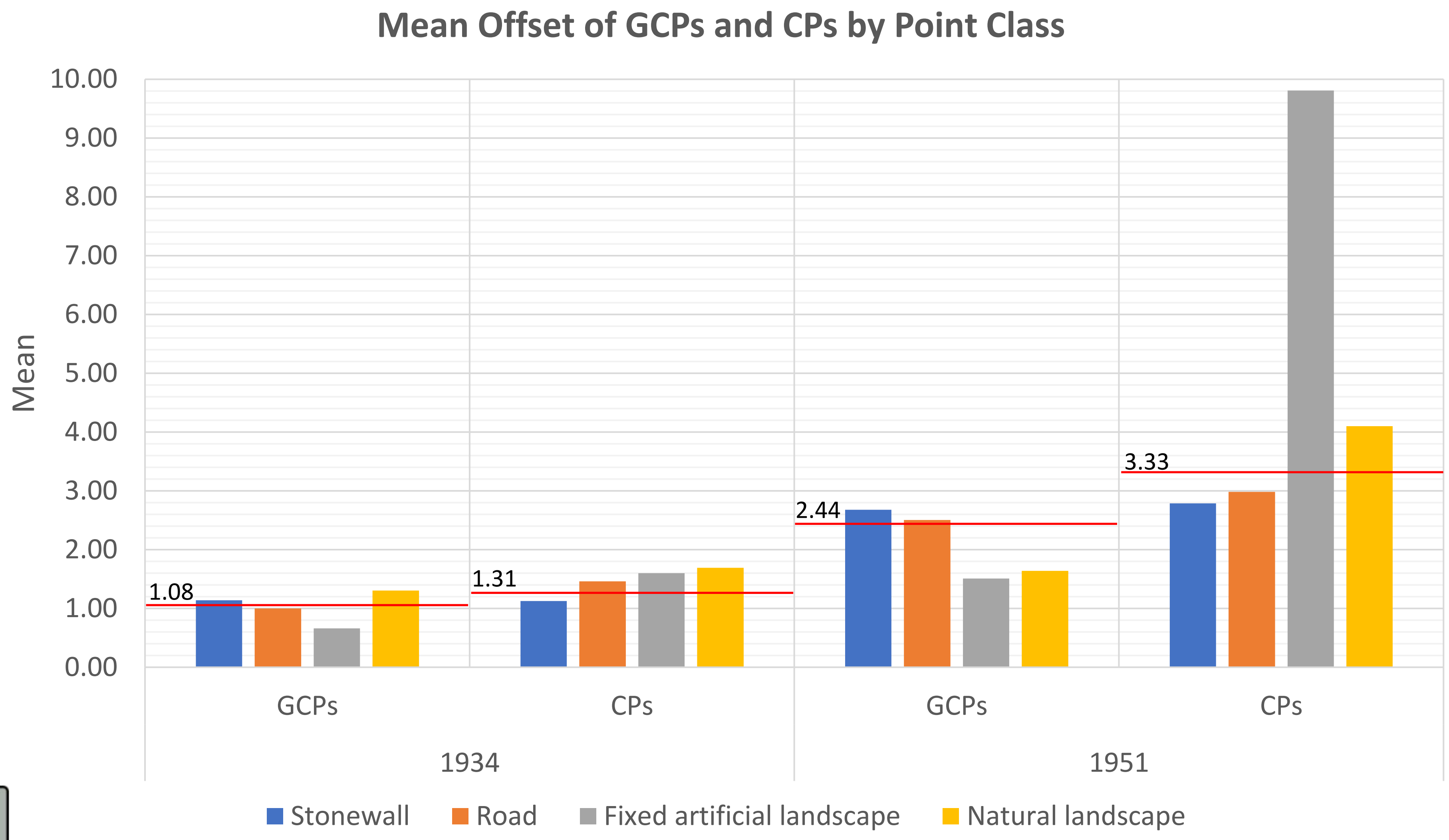
- Offset was calculated based on Euclidean distance
- The reference points (GCP and CP) from margin area show the large offsets compared to those from inside area

Vector Plots of GCP and CP Offset





The Comparison of GCP and CP Offsets by Point Type



IV. Discussion and Conclusion

IV. Discussion & Conclusion

The factors affecting the horizontal accuracy of orthophoto

1) The number of reference points (GCPs and CPs)
   - Trend: # reference points ↑, accuracy ↑
2) The distribution of reference points (GCPs and CPs)
   - Ideally, even distribution of reference points can increase accuracy. However, a number of reference points from stonewall (relatively static points), road intersection can help to get acceptable accuracy of orthophoto in terms of 19990 ASPRS standard
3) The location of reference points (margin area vs. inside area)
   - Trend: inside area shows higher accuracy compared to margin area
4) The resolution of orthomosacics
   - High resolution shows higher accuracy (e.g. 1934: 0.3m vs. 1951: 1m)
5) The position of cameras
   - Trend: the larger lateral distance between cameras, E-W offsets as well as high offsets can take place
6) Season that air photo were taken
   - leaf-on photo (i.g. 1951): it is difficult to place reference points at exact location due to tree cover

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7. Zomeni, M., J. Tzanopoulos, and J. D. Pantis. 2008. Historical analysis of landscape change using remote sensing techniques: An explanatory tool for agricultural transformation in Greek rural areas. Landscape and Urban Planning 86 (1):38–46.

Thank you

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