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Mapping forest disturbances by combining Landsat image composites and Unmanned Aerial Systems

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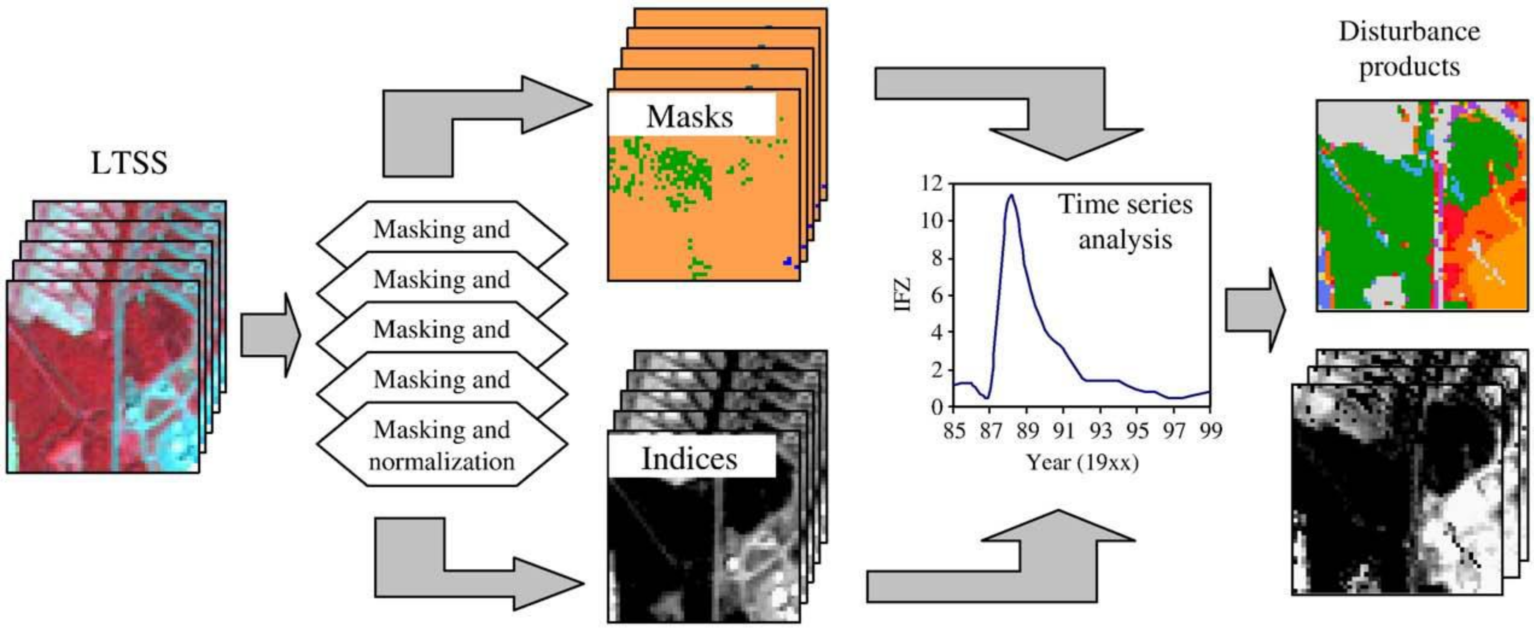
Forest disturbances

- Forest **disturbance and recovery** are critical **ecosystem processes** and an improved monitoring of changes in forest structure is needed to quantify natural and human impact on forest systems.
- **Landsat's temporal and spatial coverage**, moderate spatial resolution, and long history of earth observations provide a unique opportunity for **characterizing vegetation changes.**

Forest disturbances

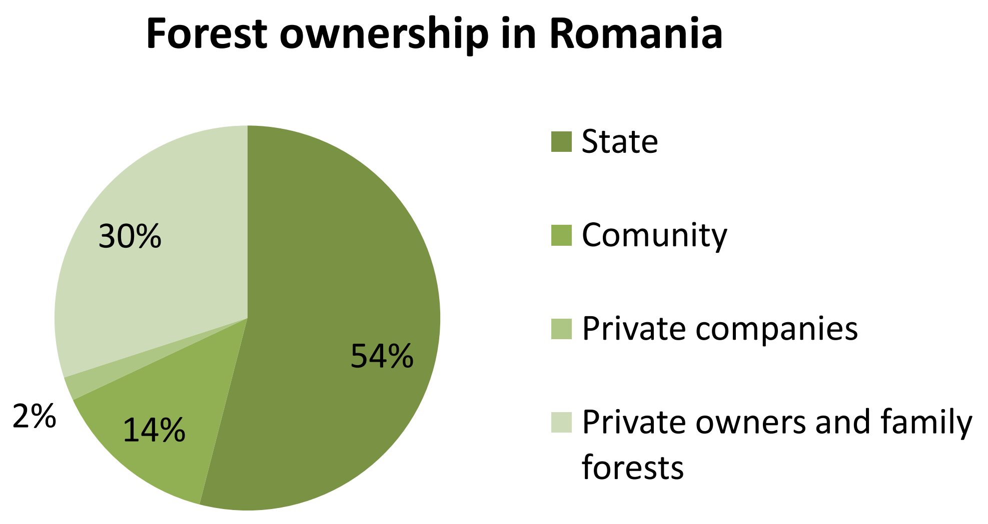
- On macro level, mapping forest disturbances with **Landsat** offers a **large view** on forest disturbances which occur during a **management** cycle.



EXAMPLE: The Vegetation Change Tracker algorithm uses the spectral-temporal properties of Landsat Time Series Stacks to produce forest disturbance products (from Huang et al. - 2010)

Present context

- Where forestry in the past focused on the production of a few commodities, the **evolution to small scale forestry** demands that new ways of forest management and monitoring to be adopted.
- These methods should combine past knowledge with innovative management planning strategies and up-to-date technology.

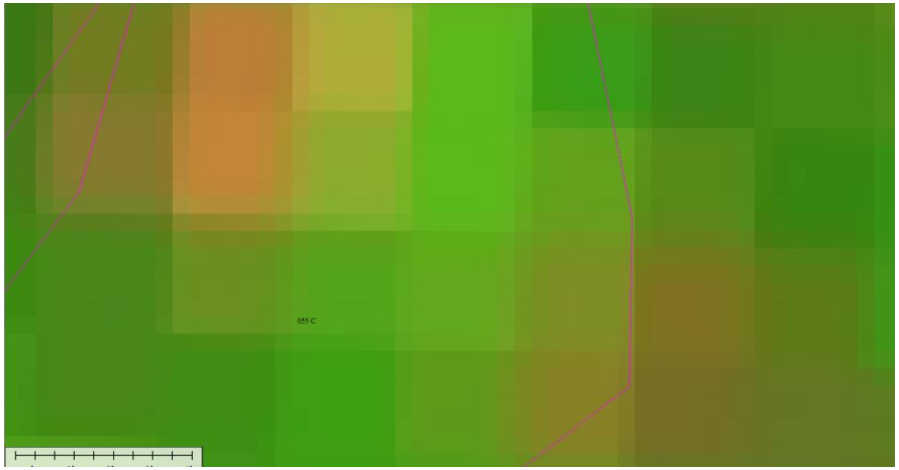


Source: National Forest Inventory, 2013

Present context

- From manager point of view, mapping forest disturbances with Landsat does **not solve the entire problem**.
- The lack of information which Landsat low spatial resolution cannot provide related to the disturbance (e.g. windthrow vs. illegal logging, clear cut vs. final cut) makes the method less attractive.

UAS high spatial resolution (0.05 m/pixel)



Landsat low spatial resolution composite (30m/pixel)

Present context – Problem?

- Due to economical issues, in many cases, is preferred a more detailed analysis of the problem **using on-site observation**, than using a previous analysis based on high resolution remote sensing method.
- The forest managers need their information as fast and accurate it gets to take the decision
- The reason?.... **Not only the PRICE ... the lead time is a reason too.**

Satellite product	Price	Lead time
IKONOS (1m)	Minimum order = 2000 – 3600 $	30 – 120 days
Digital Globe (0.6 m)	Minimum order = 1500$	30 – 120 days
Worldview 2 (0.5)	Minimum order = 2200$	30 – 120 days
Source: **Walsh Environmental Scientists and Engineers**		

Present context – Solution?...UAV

- A product fast enough, accurate enough and cheaper enough to **serve small scale forest managers**
- Nowadays UAS (Unmanned Aerial Systems) technology is rapidly growing and extending. UAS make up the aerospace industry's most dynamic growth sector.
- According to a recent market study, UAV (Unmanned Aerial Vehicles) spending is on pace to double during the 2010 – 2020 period, from current worldwide expenditures of 4.3 billion euro annually to 8.2 billion euro, totalling just more **than 68 billion euro.**
- Although started as hobby for model plane enthusiasts, civil drone technology expanded especially in remote sensing area.
- The reasons are simple: **they are cheap, easy to use and offer high resolution products in short time**. Based on this, a high resolution remote sensing method becomes attractive to forest managers interested in mapping forest disturbances.

Methodology

Forest disturbance detection algorithm based on Landsat (10 days –> 1 month)

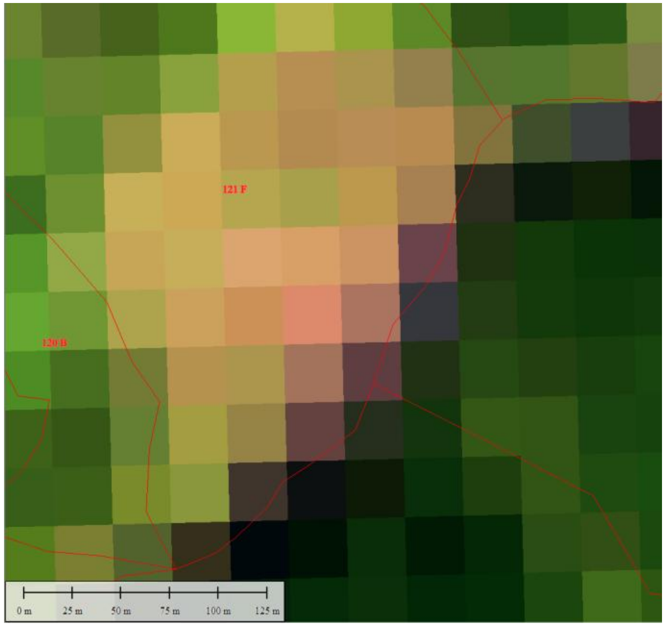
Yes

Identify the disturbed area

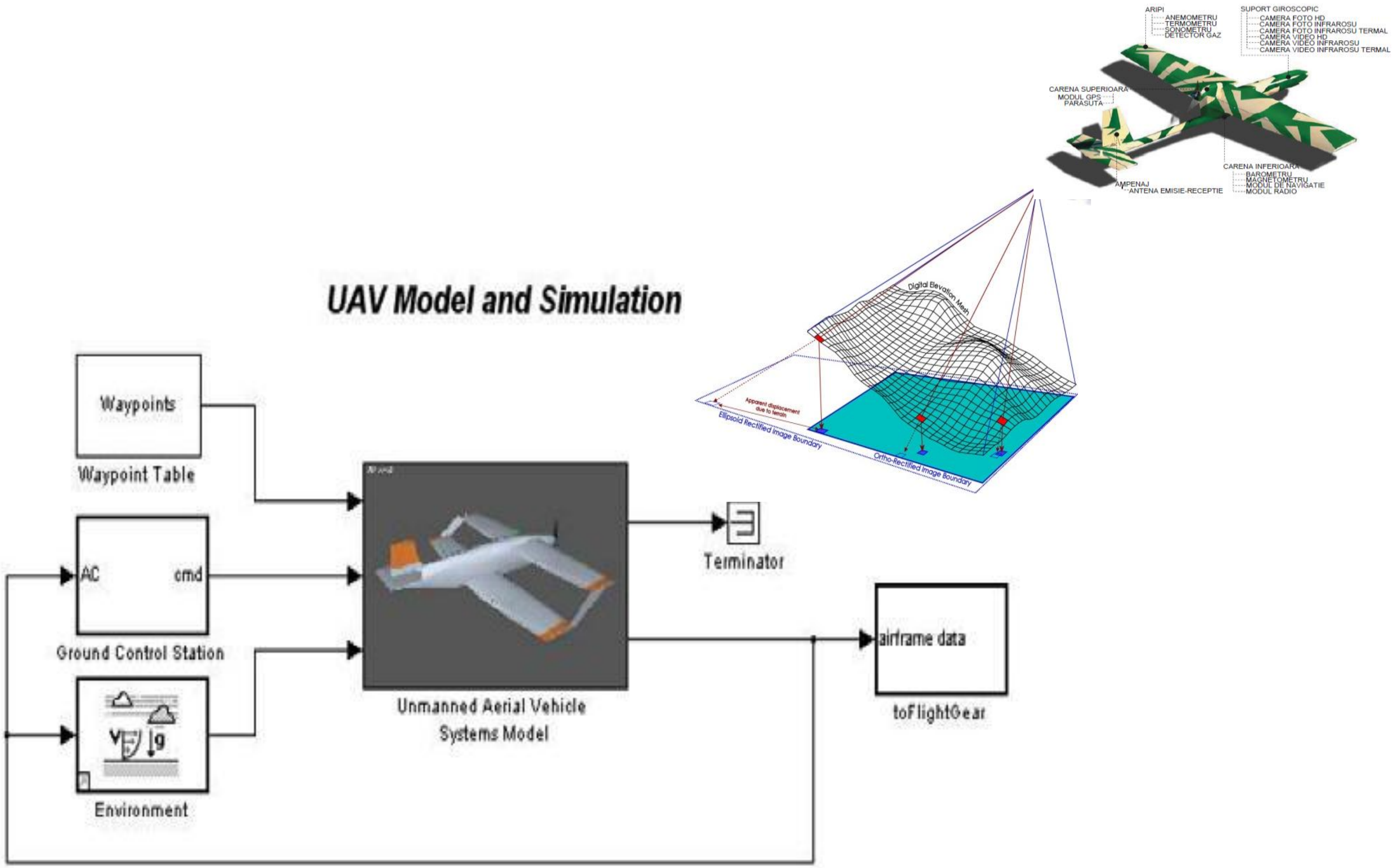
No Disturbance

Mapping area with UAV

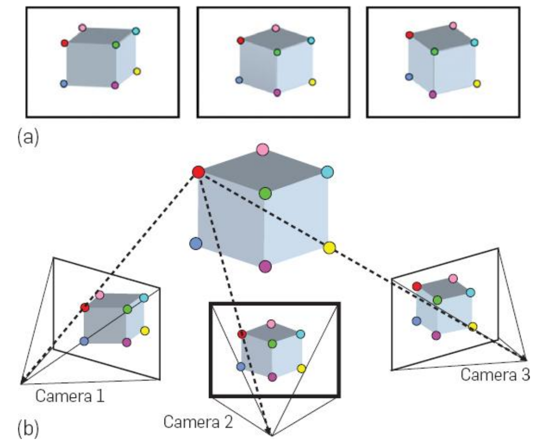
Deliver product



UAS – Unmanned Aerial System

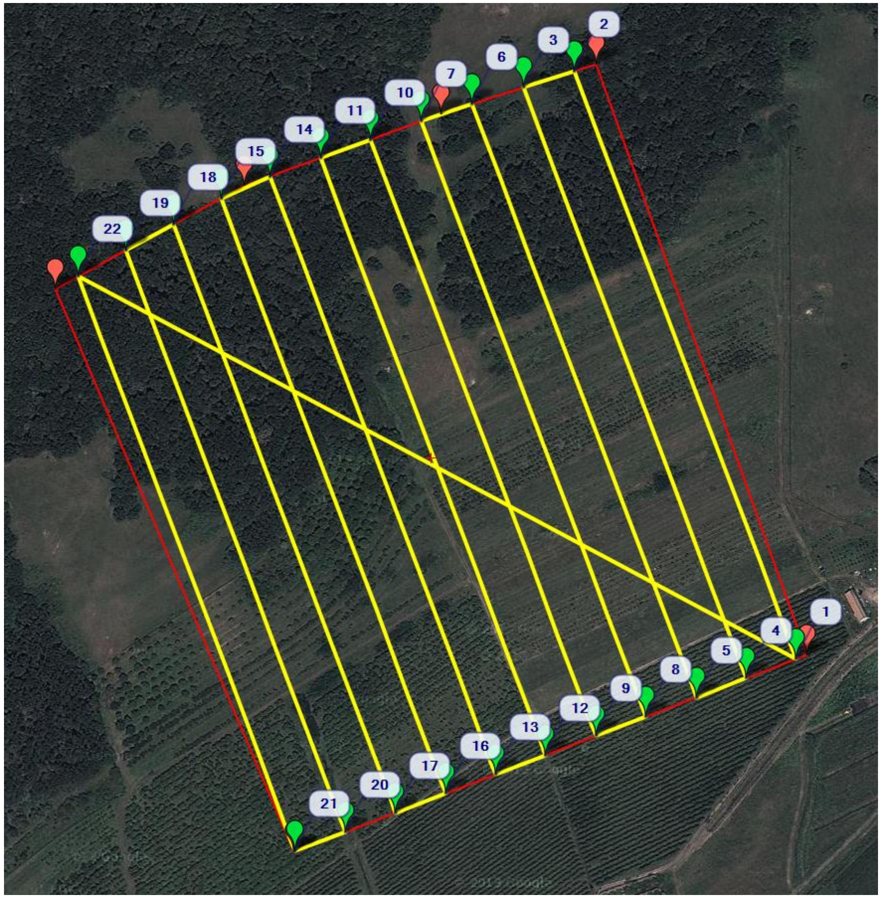


Steps in producing UAV data



- Identifying the area
- Producing the Flight plan
- Data acquisition
- Data processing (Structure from Motion)
- Georeferencing
- Extracting the products

Flight plan



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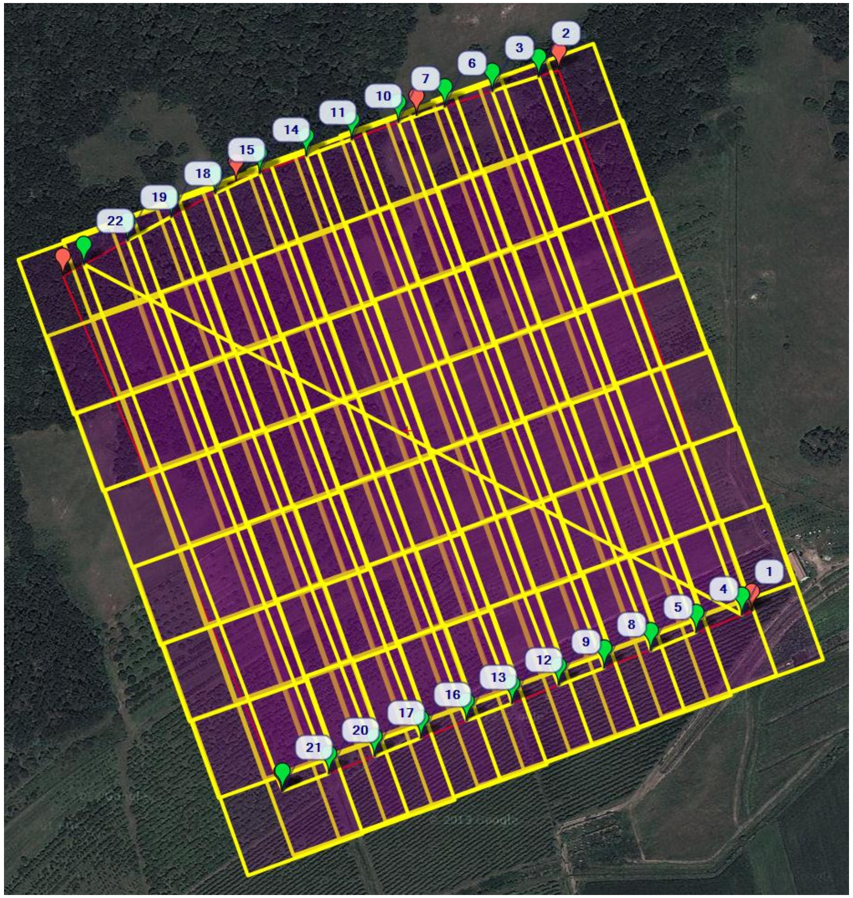

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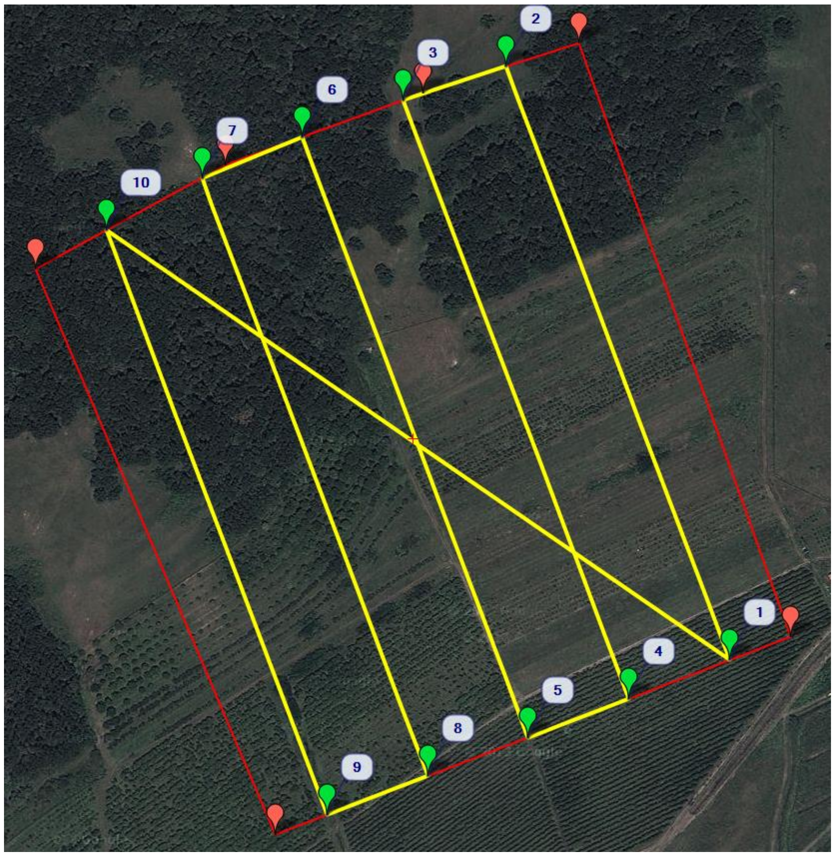
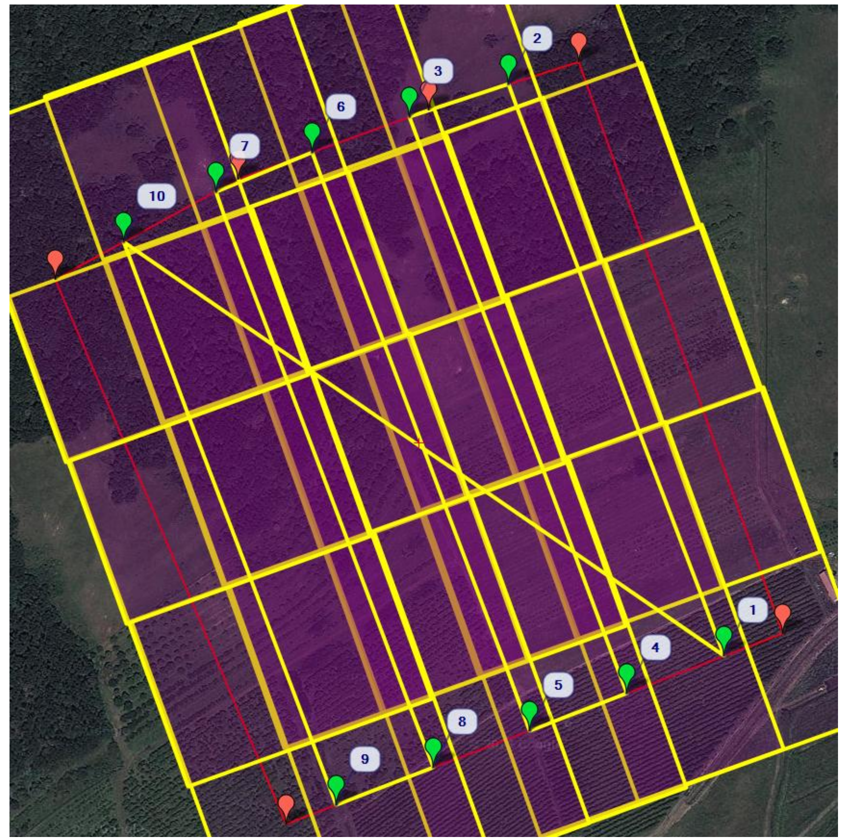
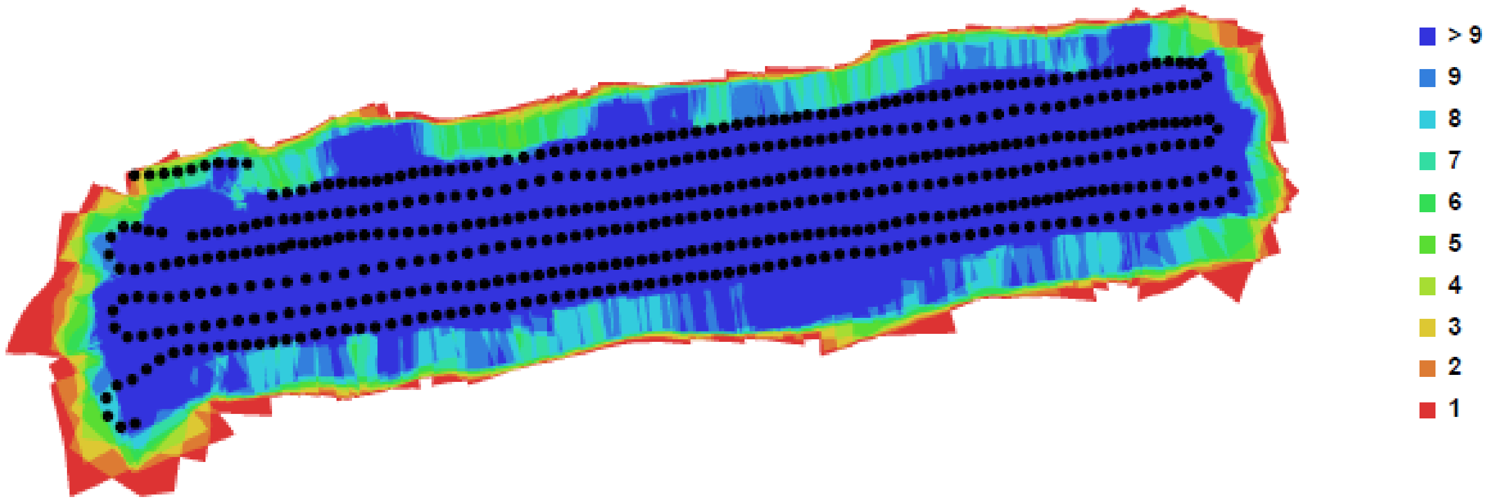
Flight plan

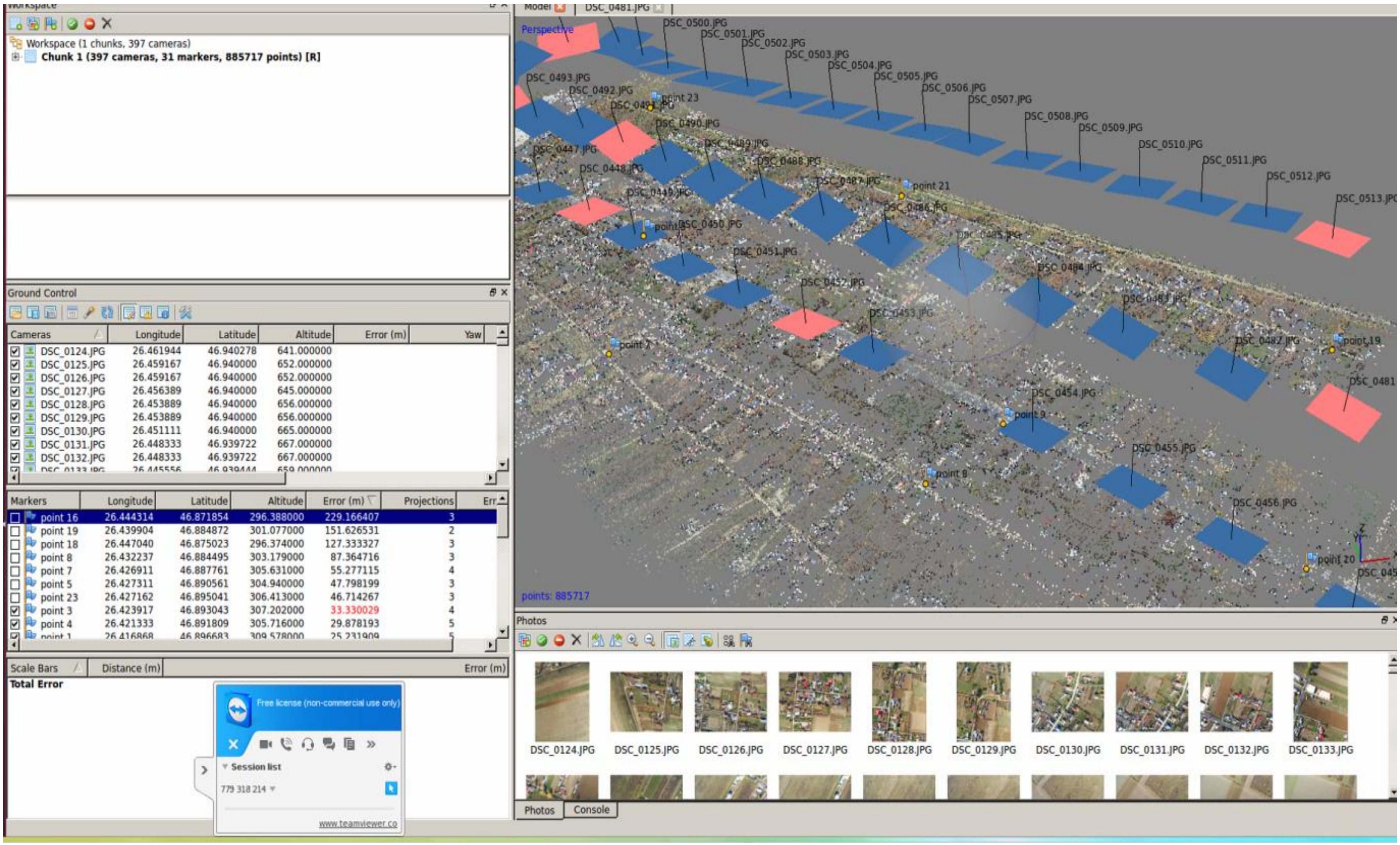




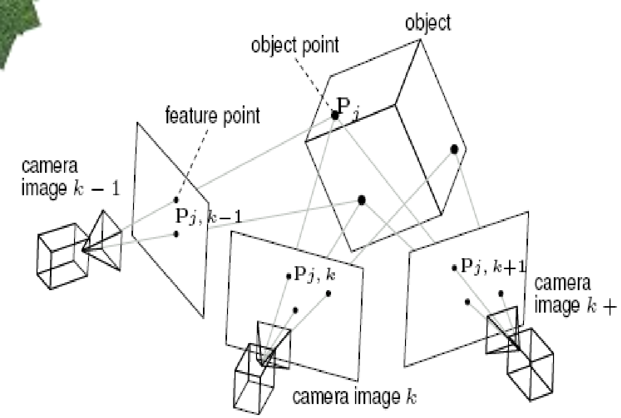
Data acquisition



Data processing



Georeferencing – ground control points



Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
point 1	0.007806	-0.016210	0.025177	0.030945	11	1.106495
point 2	-0.012901	0.014468	-0.168445	0.169557	6	2.113992
point 3	-0.019241	-0.021600	-0.065353	0.071469	13	0.505121
point 4	0.033561	0.041795	0.192248	0.199581	7	0.548978

Georeferencing

BEFORE using ground control points

Markers	Longitude	Latitude	Altitude	Error (m)	Projections	Err
☐ point 16	26.444314	46.871854	296.388000	229.166407	3	
☐ point 19	26.439904	46.884872	301.077000	151.626531	2	
☐ point 18	26.447040	46.875023	296.374000	127.333327	3	
☐ point 8	26.432237	46.884495	303.179000	87.364716	3	
☐ point 7	26.426911	46.887761	305.631000	55.277115	4	
☐ point 5	26.427311	46.890561	304.940000	47.798199	3	
☐ point 23	26.427162	46.895041	306.413000	46.714267	3	
☑ point 3	26.423917	46.893043	307.202000	33.330029	4	
☑ point 4	26.421333	46.891809	305.716000	29.878193	5	
☑ point 1	26.416868	46.896683	309.578000	25.231909	5	

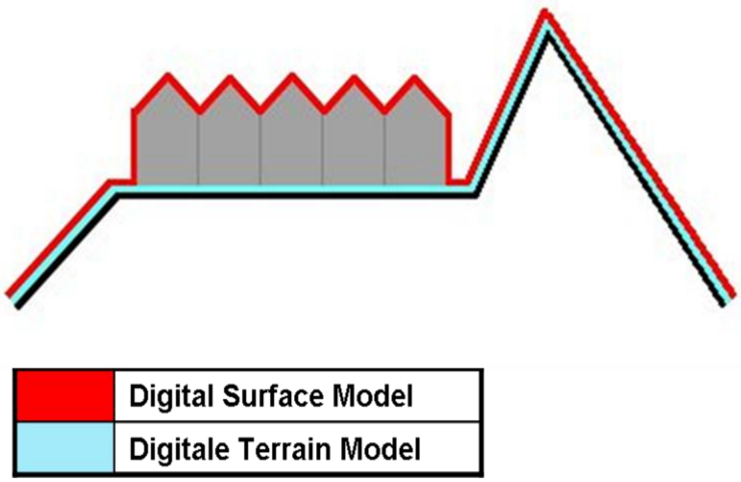
AFTER using ground control points

Markers	Longitude	Latitude	Altitude	Error (m)	Projections	Err
☐ point 7	26.426911	46.887761	305.631000	2.642843	4	
☑ point 5	26.427311	46.890561	304.940000	1.089449	3	
☑ point 1	26.416868	46.896683	309.578000	1.015263	5	
☑ point 2	26.418905	46.894747	308.517000	0.700830	5	
☑ point 3	26.423917	46.893043	307.202000	0.534738	4	
☑ point 4	26.421333	46.891809	305.716000	0.443556	5	
☐ point 21					3	
☐ point 20						
☐ point 22						
☐ point 24						

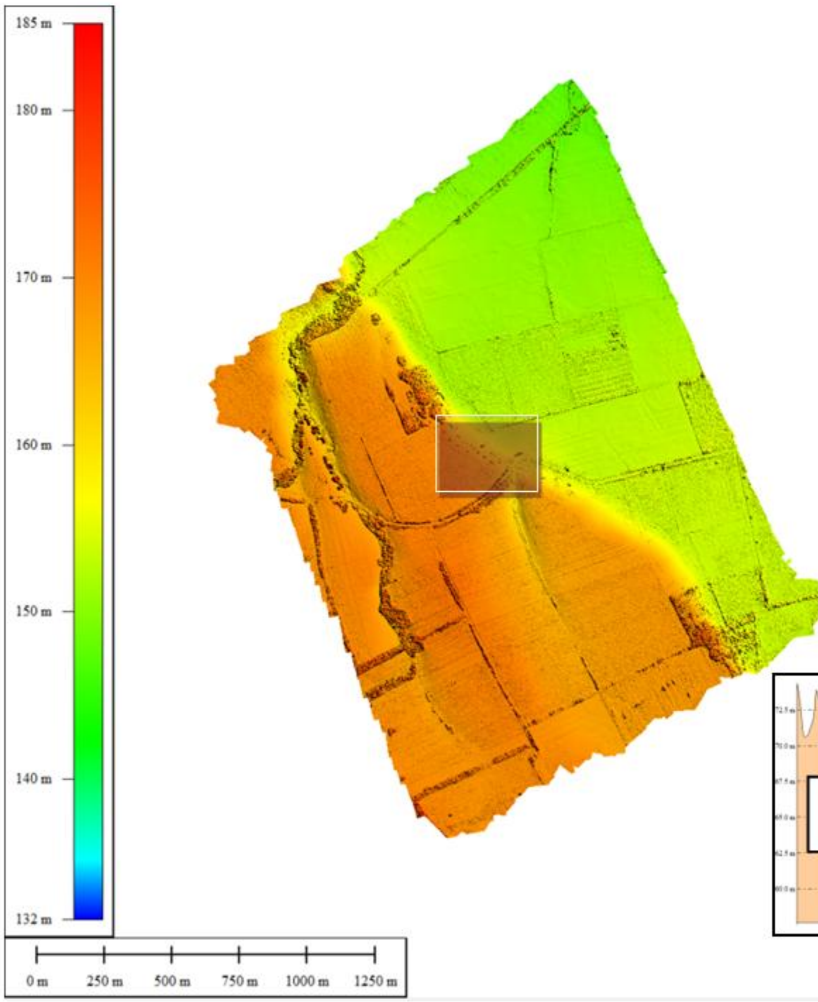
Results

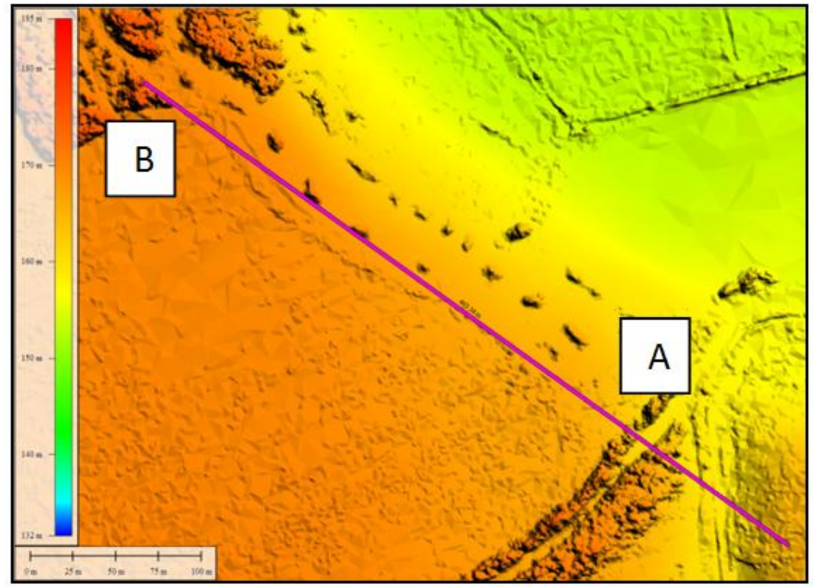
Ortorectified mosaic

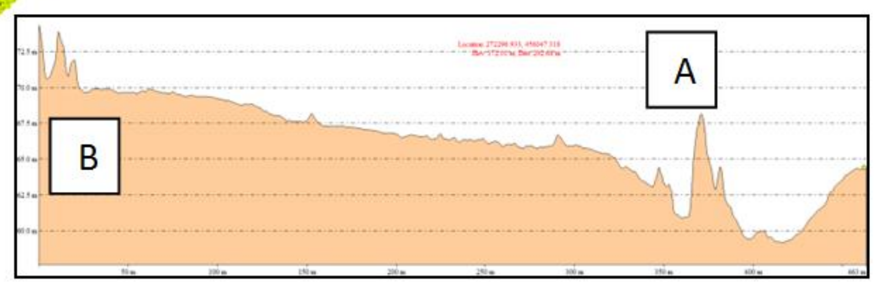
Digital Surface Model (DSM)



Digital surface model







Examples

DOBRESTI
OITUZ
LUGOJ
Romania
Moldova
Serbia
Mukacheve
Kolomyya
Chernivtsi
Mohyliv-Podil's'kyi
Briceni
Soroca
Miskolc
Nyíregyháza
Eger
Gyöngyös
Hatvan
Debrecen
Vynohradiv
Sighetu Marmației
Satu Mare
Carei
Baia Mare
Vișeu de Sus
Dorohoi
Rădăuți
Botoșani
Suceava
Floresti
Camenca
Balti
Ribnita
Pervomaisk
Vradiivka
Marghita
Gura Humorului
Fălticeni
Pașcani
Iași
Călărasi
Dubasari
Zalău
Năsăud
Dej
Cegléd
Szolnok
Oradea
Bistrița
Gherla
Piatra Neamț
Roman
Chisinau
Tiraspol
Bender
Reghin
Cluj-Napoca
Békéscsaba
Beiuș
Gyula
Târgu Mureș
Bacău
Vaslui
Huși
Slobozia
Sălcuța
Odessa
Bilyaivka
Turda
Odorheiu Secuiesc
Miercurea Ciuc
Kiskunhalas
Hódmezővásárhely
Szeged
Arad
Mediaș
Sighișoara
Bârlad
Comrat
Alba Iulia
Bilhorod-Dnistrovs'kyi
Deva
Cahul
Timișoara
Sibiu
Sfântu Gheorghe
Focșani
Hunedoara
Caransebeș
Petroșani
Săcele
Galați
Reni
Izmail
Kiliya
Vylkove
Novi Sad
Zrenjanin
Lupeni
Râmnicu Vâlcea
Buzău
Brăila
Tulcea
Sulina
Vršac
Reșița
Câmpina
Mizil
Inđija
Târgu Jiu
Pitești
Târgoviște
Ploiești
Belgrade
Požarevac
Orșova
Drobeta-Turnu Severin
Slatina
Bucharest
Cernavodă
Craiova
Negotin
Constanța
Bor
Zajecar
Vidin
Costinești
Čačak
Kragujevac
Lom
Giurgiu
Mangalia
Ruse
Kraljevo
Svishtov
Dobrich
Razgrad
Ivanjica
Krusevac
Belotintsi
Pleven
Byala
Balchik
Sjenica
Niš
Montana
Shumen

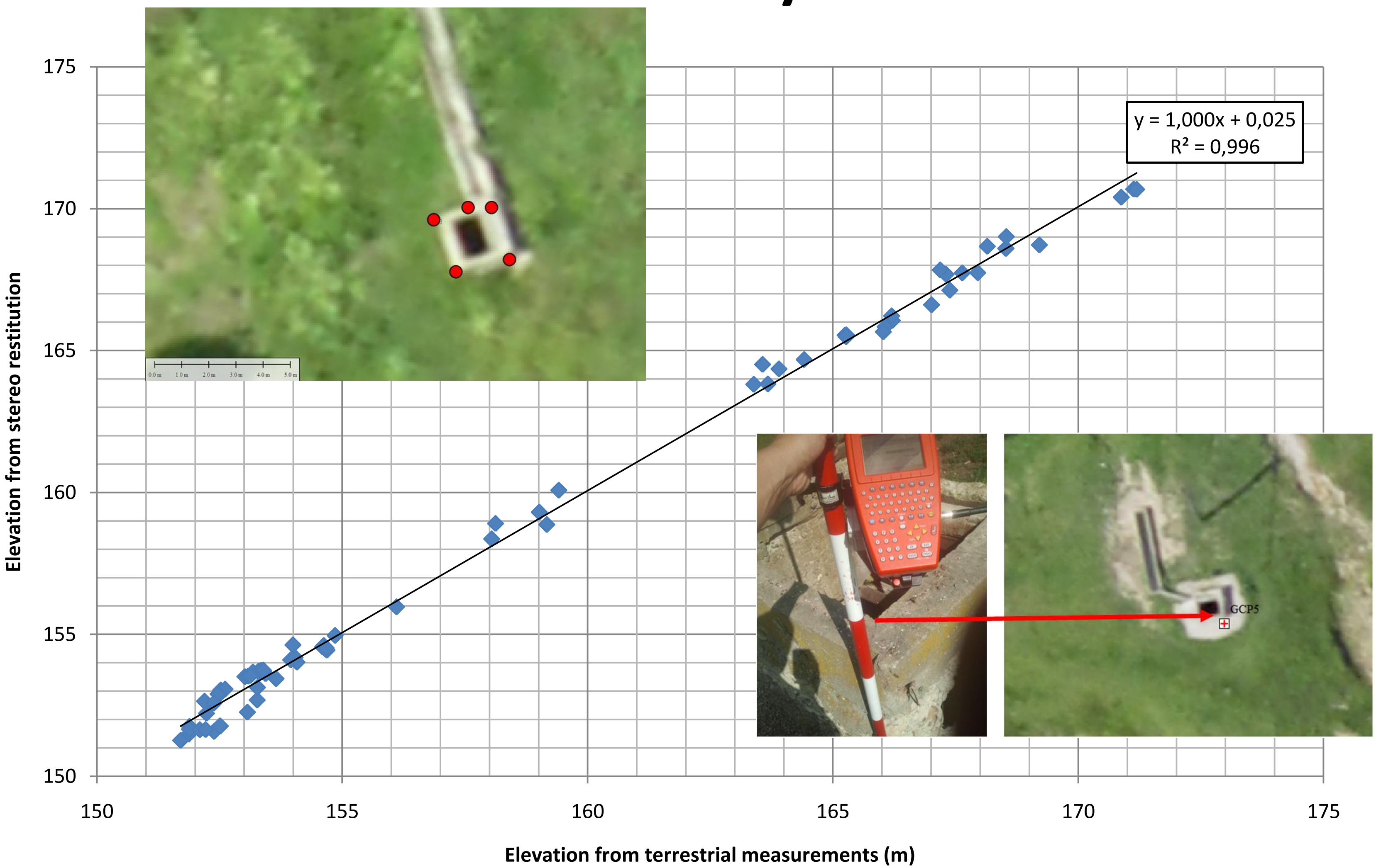
CASE STUDY: LUGOJ. Covered Area 15 square kilometers

RESULTS

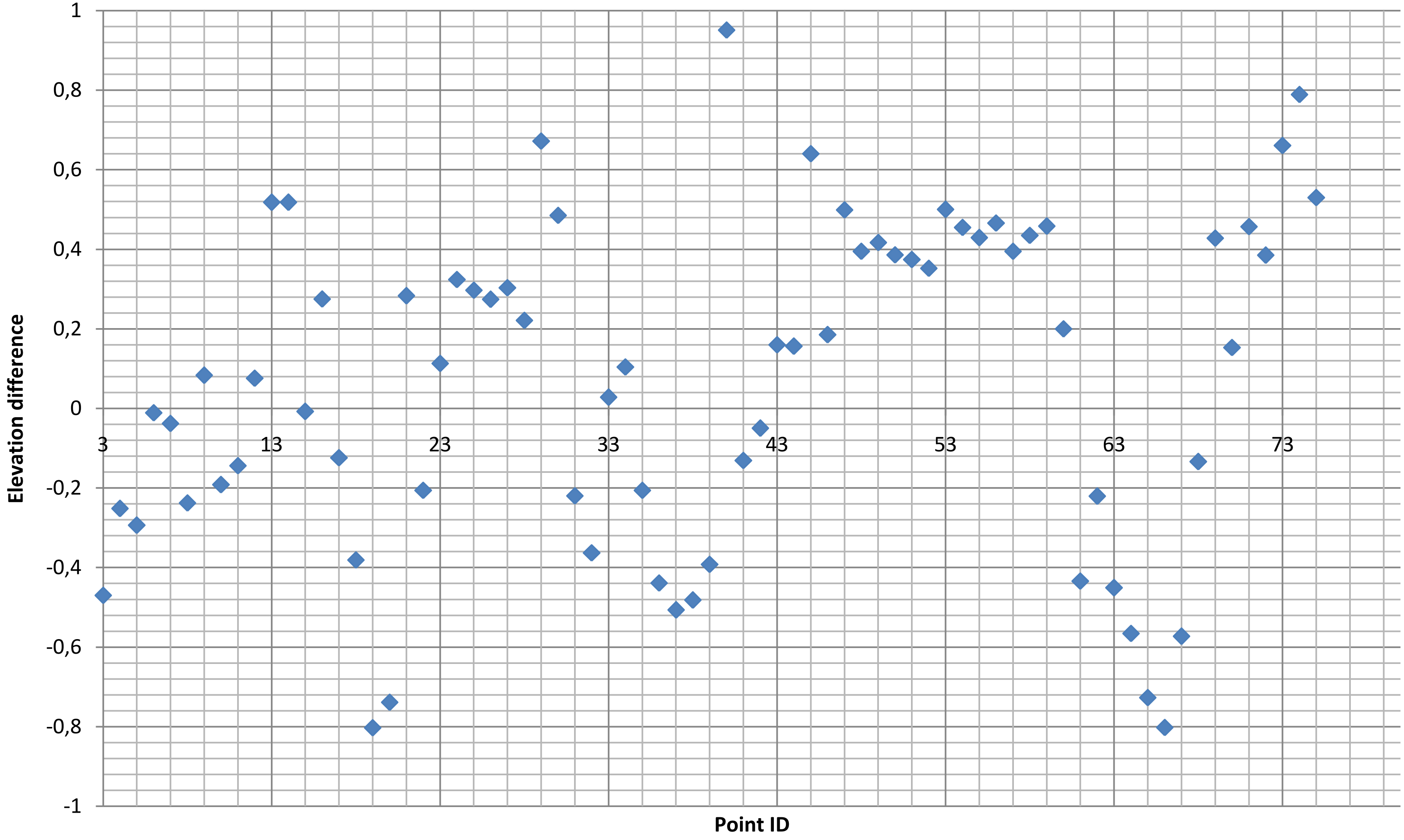
Synthetic data

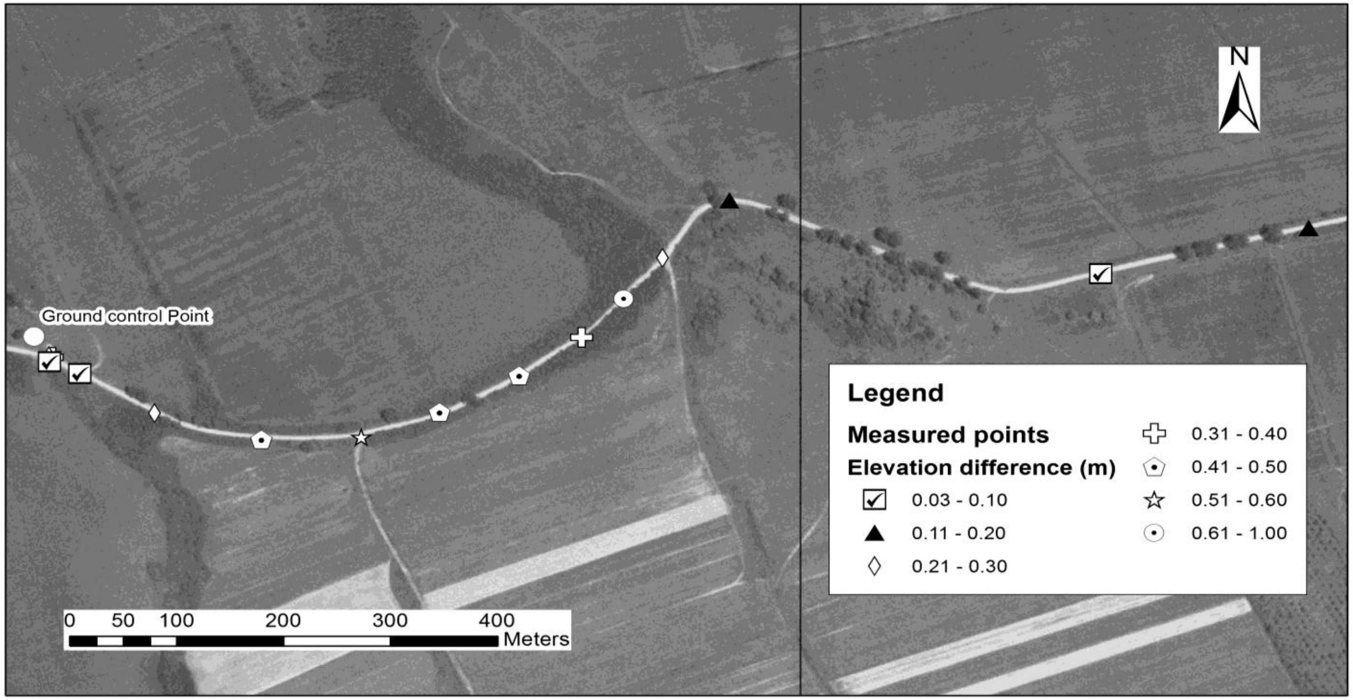
- Flight area: 1500 hectares
- Flight time: 1 day
- Data processing: 3 days
- Georeferencing: 1 day
- Flight Costs: 80 euro

Accuracy

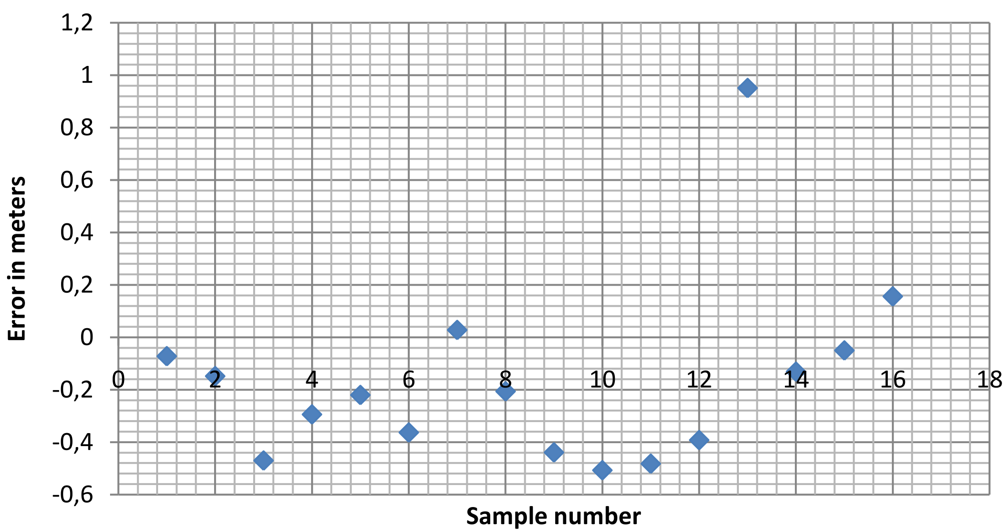

y = 1,000x + 0,025
R² = 0,996
175
170
165
160
155
150
Elevation from stereo restitution
150
155
160
165
170
175
Elevation from terrestrial measurements (m)
GCP5

Elevation precision

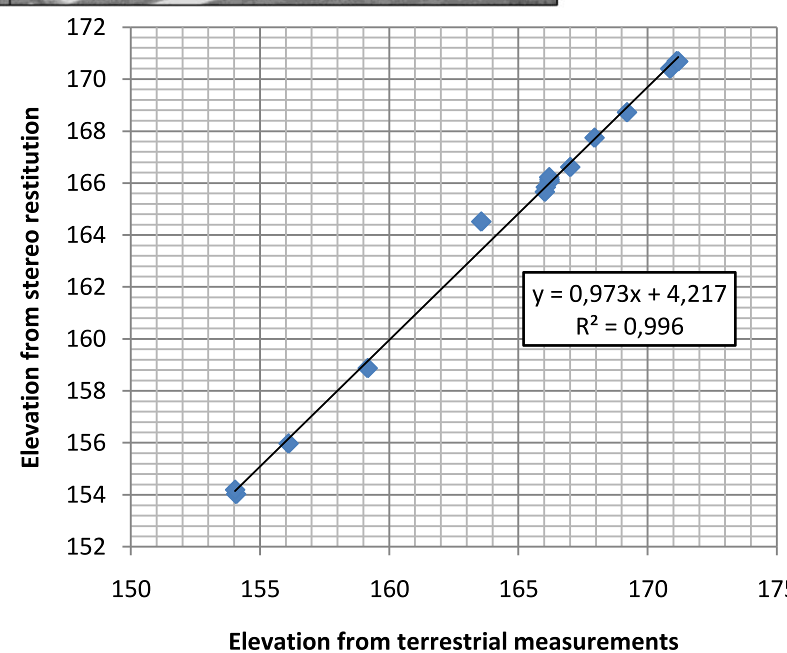




Ground control Point
N
Legend
Measured points
Elevation difference (m)
0.03 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 1.00
0 50 100 200 300 400
Meters



1,2
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
0 2 4 6 8 10 12 14 16 18
Error in meters
Sample number



172
170
168
166
164
162
160
158
156
154
152
150 155 160 165 170 175
y = 0,973x + 4,217
R² = 0,996
Elevation from stereo restitution
Elevation from terrestrial measurements

CASE STUDY: Dobrești. Covered area 30 square kilometers

RESULTS

Synthetic data

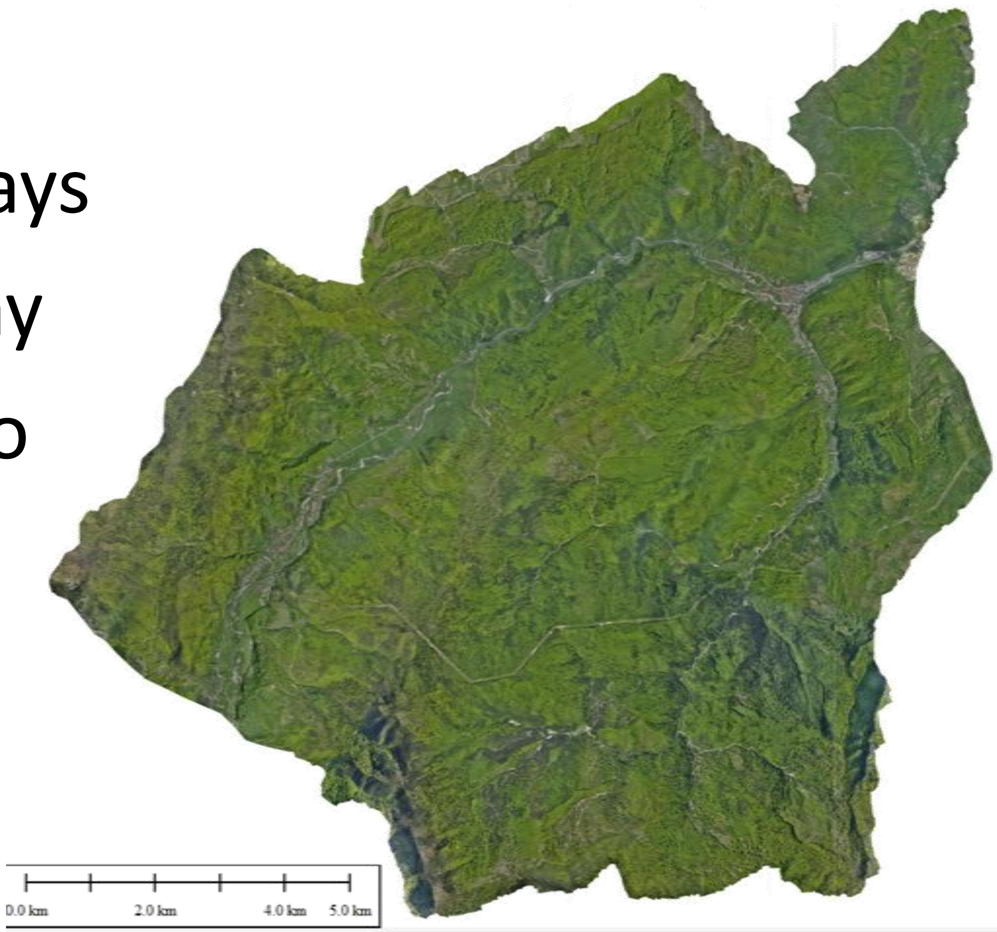
- Flight area: 3000 hectares
- Flight time: 2 day
- Data processing: 3 days
- Georeferencing: 1 day
- Flight Costs: 160 euro

CASE STUDY: OITUZ. Covered area 100 square kilometers

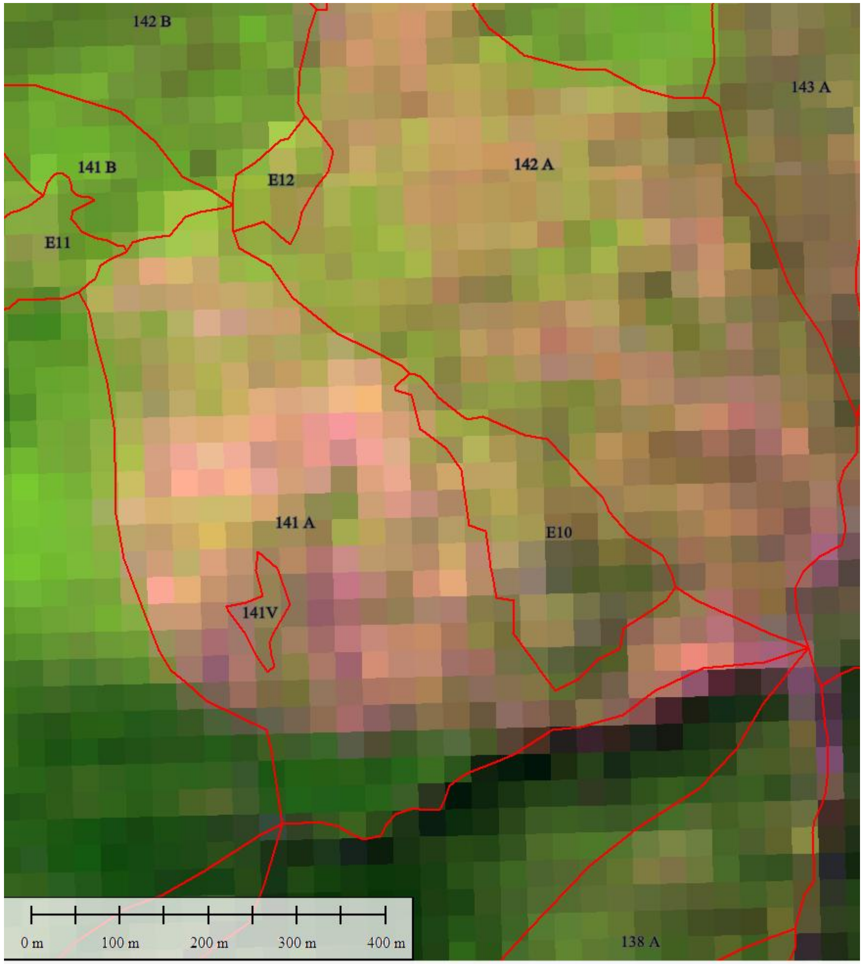
RESULTS

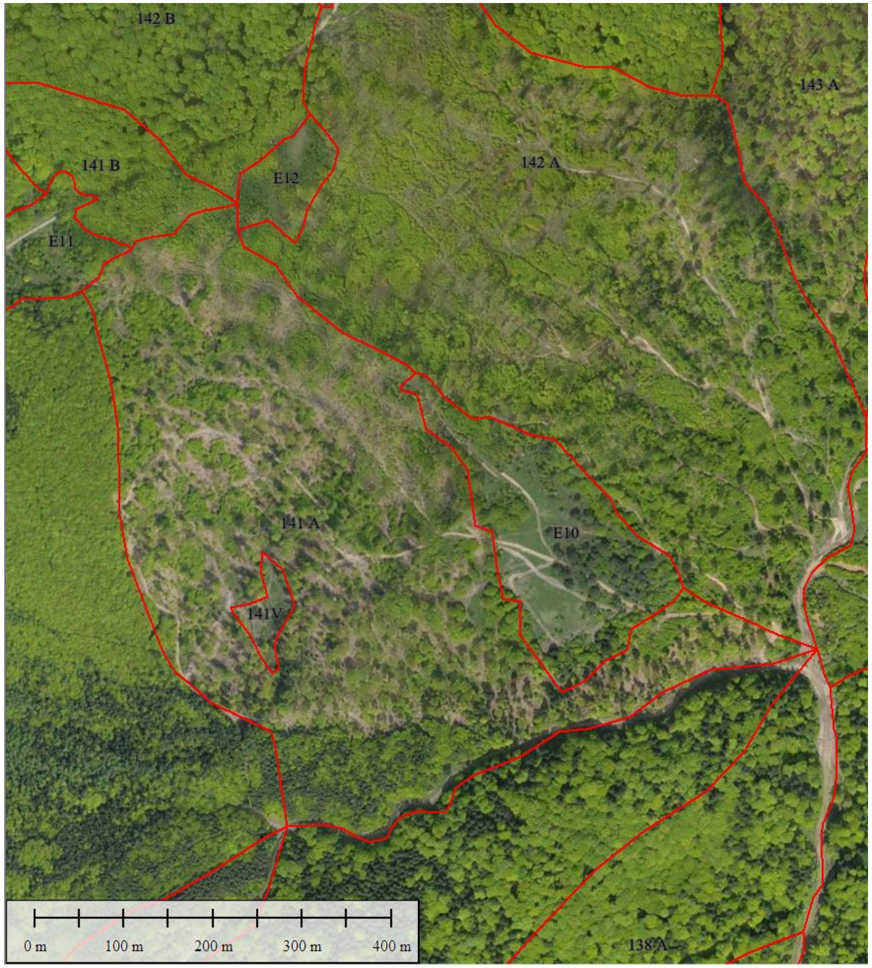
Synthetic data

- Flight area: 10000 hectares
- Flight time: 4 days
- Data processing: 6 days
- Georeferencing: 1 day
- Flight Costs: 600 euro

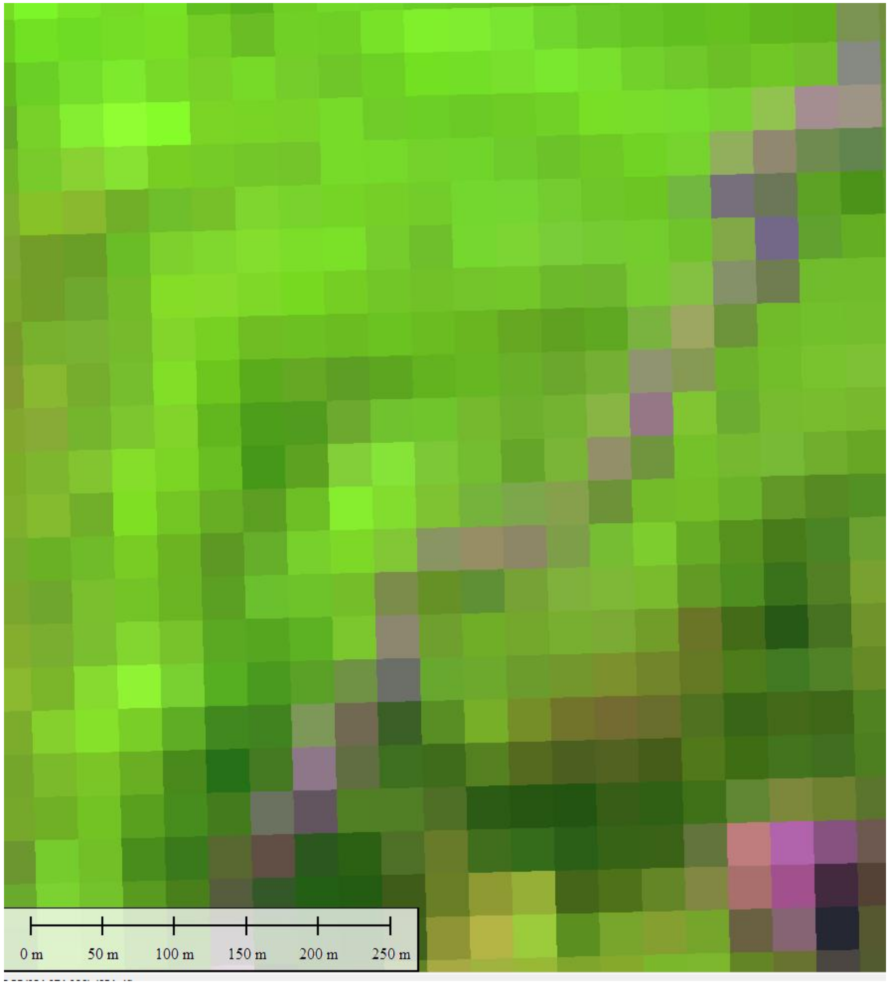


Examples

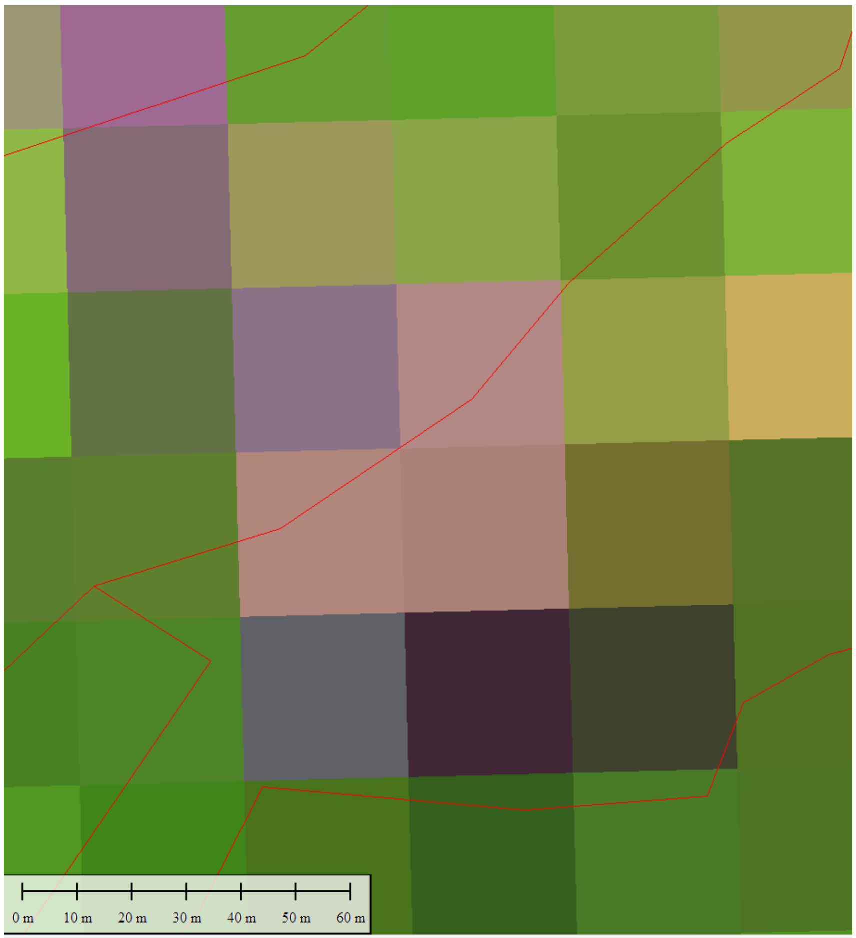

142 B
143 A
141 B
E12
142 A
E11
141 A
E10
141V
138 A
0 m
100 m
200 m
300 m
400 m


142 B
143 A
141 B
E12
142 A
E11
141 A
E10
141V
138 A
0 m
100 m
200 m
300 m
400 m

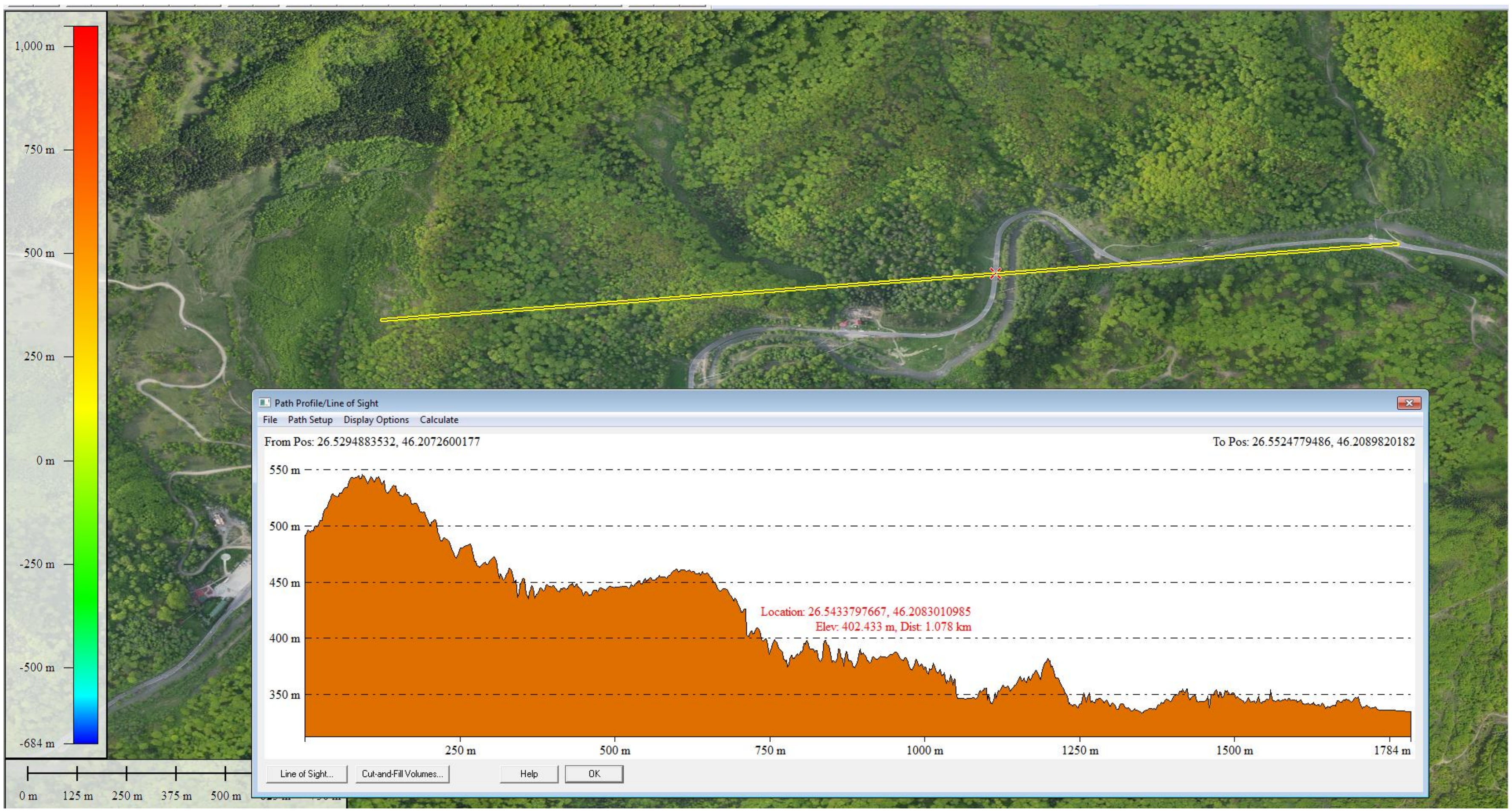
Examples



Examples



Examples – Digital Surface Model



Conclusions

- UAS technology of taking photos with UAV and obtaining complex info as digital surface model and orthorectified mosaic represents an **innovative methodology**
- The techonology offers rapid response (few days) on quite large areas (400 hectares/hour)
- The costs of producing data are lower than the actual market

Conclusions

Start-up

UAV: 5k – 70k Euro

Pilot training: 1000 euro

Processing computer: 2000 euro

Total : starting from **10000 euro**

Thank you for attention!