AUTOMATIC DRAINAGE EXTRACTION FROM REMOTE SENSING DATA

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Abstract

The hydrological network analysis was based for many years on the topographic maps of the Hellenic Military Geographical Service (HMGS). The evolution of GIS software and the existence of many satellites acquiring stereo data with global coverage made possible the DSM creation and the automatic drainage extraction. In this study the suitability and the accuracy of drainage network derived from ALOS PRSIM remote sensing data are validated with reference to the respective information from the topographic maps of 1/50.000. A fifth order sub-basin of Alfios river in Western Peloponnese was selected for the validation.

INTRODUCTION

The automatic DSM generation has become an important part of international research in the last 10 years as a result of the existence of many satellite sensors that can provide stereo pairs. Many new algorithms have been developed, the performances of which have been assessed and reported in the literature [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]. Especially studies on the accuracy of ALOS PRISM data have been also published [11], [12].

The aim of this study is to evaluate ALOS Prism stereo-data for their suitability to derive topographical and hydrological parameters using as reference the topographic maps of 1/50.000. The identification of drainage networks as quoted in [13] can be achieved using traditional methods as field observation and topographic maps or advanced methods using DEM and remote sensing. Concerning traditional methods we do not have the real representation of the drainage network because of the cartographic generalizations and subjective judgments of cartographers. In another study [14] it is mentioned that "remote sensing data has the advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time in hydrological studies".

The area of study is situated in western Peloponnese. A fifth order sub-basin of Alfios river is selected for the validation. Two PRISM data sets acquired on 2008 and 2009 respectively were used in this study. ALOS data was provided by the European Space Agency. The 2008 set contains three scenes collected from the three radiometers. The 2009 set contains only the nadir and forward images. Thus four different stereo-pairs were used for the creation of four ALOS DSMs over the same area. Twenty-five ground control points and more than one hundred tie points were used. For all the stereo-pairs the same gcp’s were used. Four DSMs with a pixel size of 7,5m were created. No further processing (editing) was done to the four DSMs.

After a first control for random or systematic errors the automatic drainage extraction was performed to the four DSMs in ARCGIS. Drainage networks were extracted from each of them. The extracted networks are compared with network digitized from the topographic map of the Hellenic Military Geographical Service (Figures 1 and 2). HMGS network has been used as a reference to the true river network. The extraction of drainage networks from the DEMs at the study area was carried out using the ArcHydro extension within ArcGIS 9.3 and Spatial Analyst Tools (Hydrology). ArcHydro tools are based on D8 algorithm [15]. We repeated the automatic extraction many times using different threshold values (50, 200, 500). As the threshold value

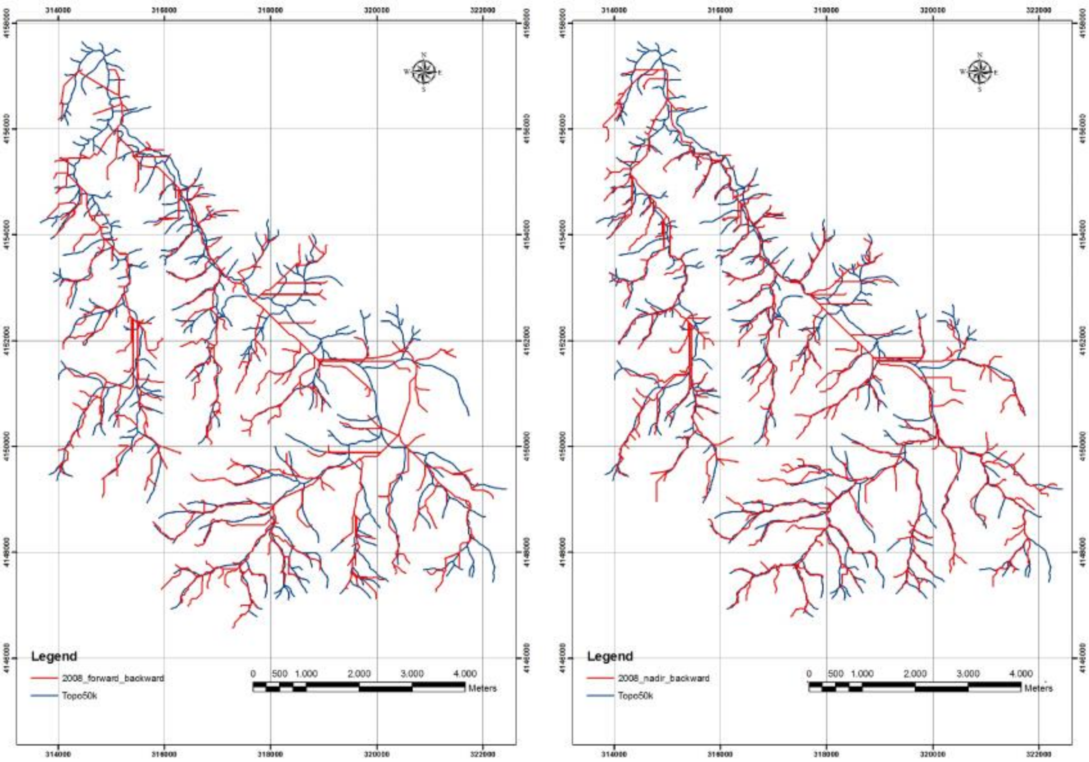

Figure 1: At the left: The extracted drainage network from the ALOS 2008 forward-backward stereo pair. At the right the extracted drainage network from the ALOS 2008 nadir-backward stereo pair. The reference network from the topographic maps is presented with blue colour.

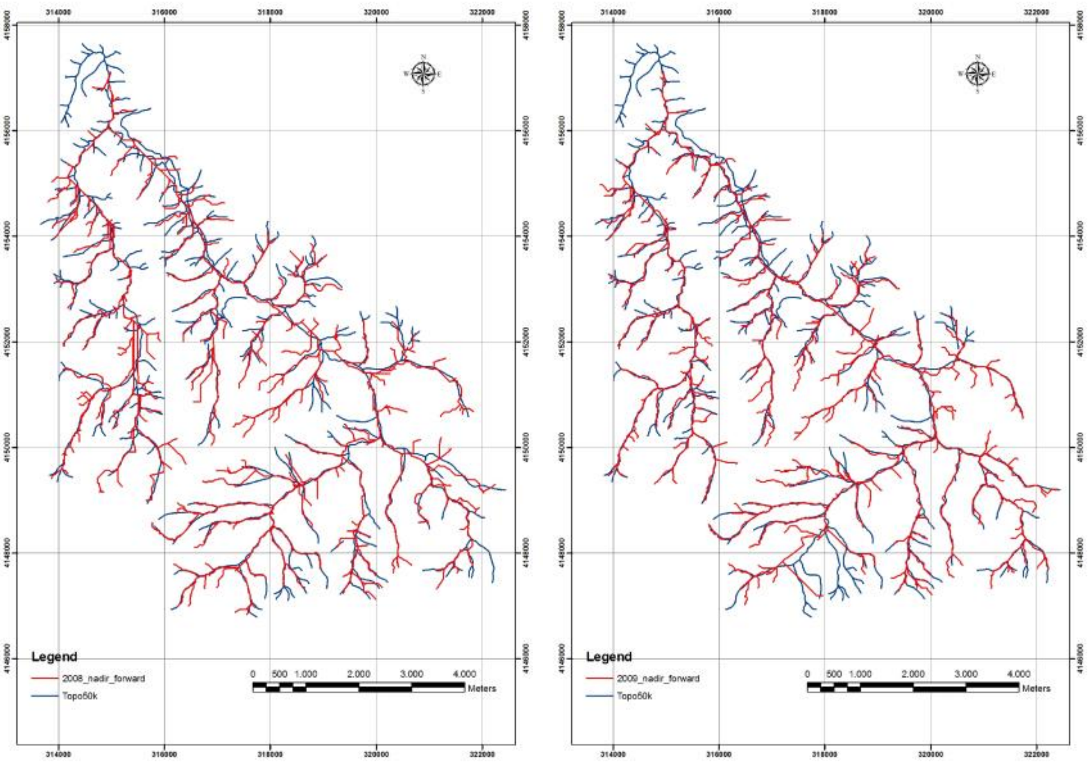

Figure 2: At the left: The extracted drainage network from the ALOS 2008 forward-backward stereo pair. At the right the extracted drainage network from the ALOS 2008 nadir-backward stereo pair. The reference network from the topographic maps is presented with blue colour.

decreases more branches are being created. In order to quantify the differences between the official drainage network that was digitized from the topographic maps and the extracted drainage networks from the ALOS DSMs the Horton's first and second laws were used. The results are presented and analyzed in the next paragraphs.

RESULTS

For the application of the first law of Horton the number of branches of the river networks under study was measured and the branching ratio (Rb) was also calculated, giving the ideal number of branches for each order and the deviations between the actual and ideal values. The tables 1-5 present the results of applying the first Horton's law for each of the studied hydrographic networks.

A first remark is that the derived networks from the ALOS DSMs presents a higher number of first order branches and a lower number of second order branches compared to the digitized network. The average branching ratios (Rb) of the extracted networks present small fluctuations and in general there are quite similar to the branching ratio of the digitized network. From all the tables It is observed that the number of the extracted branches of the hydrographic network is less than the ideal values, with the largest negative deviation in the fourth order branches (Tables 1-5). This is an index that the existing hydrographic network haven't reach its maturity level (ideal values).

For the application of the second law of Horton the mean length of branches was calculated through "clean" lengths of branches per order, the length ratio RL, ideal values and deviation of the actual values for the studied river networks. The tables 6-10 present the results of applying the second Horton's law for each of the studied hydrographic networks.

From Tables 6-10 it can be observed that the average length of the first order branches of the networks derived from the ALOs data is lower than the respective length of the of the first order branches of the digitized network. In contrary the average length of the second order branches of the networks derived from the ALOs data is higher than the respective length of the of the first order branches of the digitized network. These observations are in complete agreement with the results of the first Horton's law (Tables 1-5). Higher number of branches means a lower average length and vice versa.

The application of the second Horton's law (Tables 6-10) shows large negative deviations between the ideal and the actual values. As it can be observed in all the tables (all the extracted networks and the digitized network present high negative deviation values) this is an indication of the stage of youth for the river network.

The results from the application of the first and the second law of Horton to the extracted drainage network and to the digitized drainage network lead to the conclusion that the specific fifth order branch of Alfios river is in the youth stage and it is not given the required time to smooth the effects of geology and tectonics in the specific basin.

Table 1: Application of the 1st law of Horton to the drainage network derived from the 2008 forward backward DSM

Order	Nu Actual Values	Nu ideal Values	Deviation %	Rb	Rb_{av}
1	243	320	-23.98	4,96	4.22
2	49	76	-35.18	4,45	
3	11	18	-38.47	5,5	
4	2	4	-52.70	2	
5	1	1	0		

Table 2: Application of the 1st law of Horton to the drainage network derived from the 2008 nadir backward DSM

Order	Nu Actual Values	Nu ideal Values	Deviation %	Rb	Rb_{av}
1	266	360	-12.70	4.83	4.35
2	55	83	-52.63	4.58	
3	12	19	-36.72	6	
4	2	4	-54.07	2	
5	1	1	0		

Table 3: Application of the 1st law of Horton to the drainage network derived from the 2008 nadir forward DSM

Order	Nu Actual Values	Nu ideal Values	Deviation %	Rb	Rb_{av}
1	265	364	-27.235	4.14	4.37
2	64	83	-23.231	5.33	
3	12	19	-37.119	6	
4	2	4	-54.218	2	
5	1	1	0		

Table 4: Application of the 1st law of Horton to the drainage network derived from the 2009 forward backward DSM

Order	Nu Actual Values	Nu ideal Values	Deviation %	Rb	Rb_{av}
1	247	299	-17.38	4.41	4.15
2	56	72	-22.11	6.22	
3	9	17	-47.95	3	
4	3	4	-27.85	3	
5	1	1	0		

Table 5: Application of the 1st law of Horton to the drainage network derived from the Topo50K

Order	Nu Actual Values	Nu ideal Values	Deviation %	Rb	Rb_{av}
1	204	352	-42.00	2.55	4.33
2	80	81	-01.50	7.27	
3	11	19	-41.34	5.5	
4	2	4	-53.81	2	
5	1	1	0		

Table 6: Application of the 2nd law of Horton to the drainage network derived from the 2008 forward backward DSM

Order	L_u Actual Values in km	L_u ideal Values in km	L_u/L_{u-1}	$L_u$average	Deviation %
1	0.32	0.32		2.89	0
2	0.79	0.94	2.44		-0.16
3	1.18	2.71	1.50		-0.56
4	8.88	7.84	7.51		0.13
5	1.18	22.71	0.13		-0.95

Table 7: Application of the 2nd law of Horton to the drainage network derived from the 2008 nadir backward DSM

Order	L_u Actual Values in km	L_u ideal Values in km	L_u/L_{u-1}	$L_u$average	Deviation %
1	0.31	0.31		2.52	0
2	0.68	0.79	2.17		-0.14
3	1.54	1.99	2.27		-0.23
4	8.60	5.02	5.59		0.71
5	0.58	12.69	0.07		-0.95

Table 8: Application of the 2nd law of Horton to the drainage network derived from the 2008 nadir forward DSM

Order	L_u Actual Values in km	L_u ideal Values in km	L_u/L_{u-1}	$L_u$average	Deviation %
1	0.29	0.29		2.49	0
2	0.57	0.72	1.97		-0.21
3	1.64	1.80	2.87		-0.09
4	8.18	4.49	4.50		0.82
5	1.12	11.20	0.14		-0.90

Table 9: Application of the 2nd law of Horton to the drainage network derived from the 2009 forward backward DSM

Order	L_u Actual Values in km	L_u ideal Values	L_u/L_{u-1}	$L_u$average	Deviation %
1	0.29	0.29		2.80	0
2	0.63	0.81	2.18		-0.22
3	1.98	2.28	3.13		-0.13
4	2.03	6.39	1.03		-0.68
5	9.91	17.92	4.88		-0.45

Table 10: Application of the 2nd law of Horton to the drainage network derived from the Topo50K

Order	L_u Actual Values in km	L_u ideal Values in km	L_u/L_{u-1}	$L_u$average	Deviation %
1	0.38	0.38		2.18	0
2	0.35	0.83	0.93		-0.57
3	2.56	1.81	7.27		0.41
4	0.75	3.96	0.30		-0.80
5	0.18	8.63	0.23		-0.98

CONCLUSIONS

The application of the first and second Horton’s laws on the specific fifth order branch of Alfios river based on the digitized drainage networks from topographic maps and on the automatically extracted drainage networks from ALOS PRISM DSMs lead us to the following observations:

All the extracted drainage networks from the DSM show a quite good spatial overlap with the manually digitized drainage networks, and offer a quite close representation of the actual network, as far as number of branches and branch lengths are concerned.

The statistics of the two Horton's laws to all the drainage networks indicate that the specific hydrographic network haven't reach its maturity level (ideal values).

REFERENCES

1 Toutin, Th., (2001). “Elevation modelling from satellite VIR data: a review”, International Journal of Remote Sensing, 22, pp. 1097–1125.

2 Toutin, Th., (2004). “Geometric processing of remote sensing images: models, algorithms and method”, International Journal of Remote Sensing, 25, pp. 1893–1924.

3 Toutin, Th., Che Nier, R. & Carbonneau, Y., (2001). “3D geometric modelling of Ikonos Geo images”, In ISPRS Joint Workshop ‘‘High Resolution from Space’’, Hannover, unpaginated CD-ROM.

4 Zhen, X., Huang, X. And Kwoh, L.K., (2001). “Extracting DSM From Spot Stereo Images”, In 20th Asian Conference On Remote Sensing, Singapore, Unpaginated Cd-Rom.

5 Konstantinos G. Nikolakopoulos, Emmanuel K. Kamaratakis & Nektarios Chrysoulakis, (2006). “SRTM vs ASTER Elevation Products. Comparison for two Regions in Crete, Greece”, International Journal of Remote Sensing, Vol 27, No 21-22, p. 4819-4838.

6 Konstantinos G. Nikolakopoulos, Dimitrios A. Vaiopoulos, Georgios Aim. Skianis, (2004). “Comparing a DTM created with ASTER data to GTOPO 30 and to one created from 1/50.000 topographic maps”, Proc of SPIE, Vol. 5574, p. 43-51.

7 Konstantinos G. Nikolakopoulos & George Lathourakis, (2005). “Along the track vs across the track satellite stereo-pair for DTM creation”, IEEE, IGARSS 2005, Vol. 8, p. 5324- 5327.

8 Konstantinos G. Nikolakopoulos & Nektarios Chrysoulakis, (2006). “Updating the 1:50.000 topographic maps using ASTER and SRTM DEM. The case of Athens, Greece”, Proc. of SPIE Vol. 6366, p. 6366061-11.

9 Konstantinos G. Nikolakopoulos, Panagiotis I. Tsombos & Alexandra Zervakou, (2007). “Evaluating SRTM and ASTER DEM accuracy for the broader area of Sparti, Greece”, Proc. of SPIE Vol. 6746 p. 67460F1-12.

10 Panagiotis I. Tsombos, Konstantinos G. Nikolakopoulos & Lathourakis George, (2008). “DEM creation from Cartosat data and comparison to DEM from other sources”, Proc. of SPIE Vol. 7106, p.71061C1-12.

11 Panagiotis I. Tsombos, Konstantinos G. Nikolakopoulos, (2009). “DEM creation from ALOS data and comparison to DEM from other sources. A case study from Greece”. Proc. of ‘ALOS PI 2008 Symposium”, ESA SP664 Unpaginated CDRom.

12 Panagiotis I. Tsombos, Konstantinos G. Nikolakopoulos & Lathourakis George, (2009). “DSM from ALOS and comparison with airphoto DEM: the case of Thessaloniki, Greece”. Proc. of SPIE, Vol. 7478, p. 74780L1-10,

13 Ozdemir, H., Bird. D., (2008). Evaluation of morphometric parameters of drainage networks derived from topographic maps and DEM in point of floods. Journal of Environmental Geol-ogy 56 (7): 1405-1415.

14 Nikolakopoulos, K., Gioti, E. (2011). Suitability of DSM derived from Remote Sensing data for hydrological analysis with reference to the topographic maps of 1/50000. Book of Advances in the Research of Aquatic Environment 1: 121-128.

15 Liu, X., Zhang, Z. (2010). Extracting drainage network from high resolution DEM in Toowoomba, Queensland. Paper presented at the Queensland Surveying and Spatial Confer-ence 2010, Australia, September 1-3.