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Accuracy Assessment of Aster and Srtm Data W.R.T Lidar Data for Jeddah City- Ksa

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Abstract*: Most of Civil Engineering projects and Earthworks need a Digital Elevation Models (DEM), such as: infrastructure, utilities, flood hazard determination, road design, and watershed management. Furthermore, Digital Elevation Models are very important for geodetic applications and the knowledge of the earth's surface topography as well as the field of Earth sciences. In the current research work, a comparative study will be done to evaluate the accuracy come out from two available sources of DEMs. Also, this research will assess their suitability in engineering applications in the Jeddah city (KSA). Two Global DEM (GDEM) have been focused, the first one is the ASTER and the second one is SRTM3 with respect to LIDAR Data for the same regions.

The current study will concentrate on the accuracy assessment of SRTM and ASTER Data in Jeddah, KSA. The obtained result from this current research (study areas of North East, Medal East and South East) of Jeddah city for ASTER data has an accuracy inversely proportional with the roughness factor. Also, the accuracy of SRTM is an inversely proportional with the roughness factor. In this context, in flat terrain the accuracy is between about 1 m to about 2.5m, and about 5m to10 m for rolling terrain. However, it's about 20m to 30 m for mountainous terrain for ASTER data. On other words, the accuracy of SRTM on flat terrain is between about 0.5 m to less than 1.8 m, and about 6.5m to10. 5 m for rolling terrain. However, it's about 23m to 30 m for mountainous terrain. Finally, the research work is obtained that, in flat terrain, the accuracy of SRTM data is less than the accuracy of ASTER data. But the comparative accuracy between them is approximately the same for rolling terrain. However, for mountainous terrain the accuracy of ASTER data is almost better than the accuracy of SRTM data.

Keywords : (LiDAR), (DEM), (SRTM), (ASTER),(Terrain classification).

I. INTRODUCTION

Developing countries have lack of suitable topographic data. The lack of the data is an obstacle and challenge for primary studies of many engineering projects. So, Civil engineering projects and several applications need Digital Terrain model (DEM, DTM or DSM) which indicate the topography of the Earth's surface [5]. Therefore, in order to develop the concept of the initial study of any project in the civil engineering field to choose the best site for the establishment of the project need a suitable DEM[7]. For example, the selection of the site of the dams or choose the best path in the planning of roads, the path of networks (Irrigation, sewage and water network) and other applications........... Etc [8].

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In addition, providing this data through the Web with suitable accuracy for some engineering applications. So this research aims to do a comparative study between these data sources [3],[10]. These data are covering all the world. DEM data will compare with data obtained by the project of aerial photography and LIDAR survey of the study areas [2],[5].

Firstly, the data is corrected by using of a limited number of points. These points were well distributed at the study areas not less than 10% of the total number of points which needed in surveying of the entire region. The SRTM data, and ASTER data are a step-forward and helpful in topographic mapping, and supply a great advance in the availability of suitable elevation data of the developing world. This data is produced by NASA. The SRTM data save a big effort for data acquisition of geospatial science and other applications in the developing world. Also, ASTER is DEM data, which is produced by a cooperative between NASA, Japan. SRTM, covered most of the world surface with a ground resolution of 90 m, for most of the earth's surface except for the United states of America has 30m resolution, while, ASTER has a DEM with ground resolution 30-meter for all the world. Even though the accuracy of STRM was about ±20 m horizontal circular error and ±16 m vertical linear error at the 90% confidence level, many accuracy tests showed that the accuracy with accurate data is better than expected [9],[10]. The ASTER DEM product has the accuracy of DEMs frequently are more accurate than 25m RMSE xyz[6].

II. DATA PREPARATION , DATA USED, AND STUDY AREAS

Jeddah city is one the important city in KSA. Area of Jeddah is about 5000 km2. It is located between latitudes of (21° 34' 03.4458" – 21° 51' 48.2343" degree) and longitudes of (39° 11' 21.1766"- 39° 28' 54.1810" degree), see Fig. 1. Jeddah has many different terrain types from very flat surface (terrain) to very rough surface (terrain) or mountainous . In this research chose three locations in different places in Jeddah.. In this research choose three locations in different places in Jeddah everyone has 3 areas.

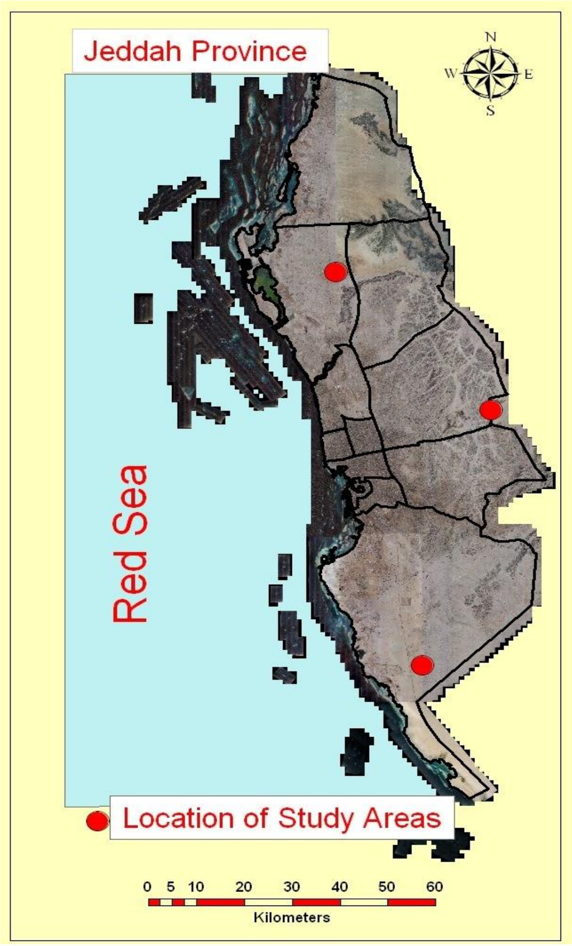

Fig.1. Jeddah city and location of study areas

III. THE USED DATA (LIDAR DATA SPECIFICATION):

In this research, the Airborne Light Detection and Ranging (LiDAR) Data Imagery was acquired to activities for Jeddah Province and it is used as trust data for comparison with GDEM data. The table (I) is illustrating the LiDAR classification and feature identification activities.

Table- I: LIDAR Data Classification (Data Used)

Item	Data
Platform	Fixed-wing aircraft
Equipment	> 100 Hz
density / points	2 pts per m
overlap	From 20% to30%
Datum	(WGS84) reference ellipsoid, (UTM_Zone 37N).
Height reference	KSA Geoid 2004
Point positioning and height accuracy	< 50 cm RMS Horizontal (95% confidence) < 15 cm RMS Vertical (95% confidence)
Returns	> 4 returns
Project area	Jeddah City
Base stations	Minimum 2
Intensity	12 bit
Quality check points	150-200 points evenly distributed across DTM area
Cross-strips	Minimum 4 Cross-strips
Imagery specifications	Resolution (GSD) maximum 10 Centimeters

IV. LOCATION:

In the current research , there are three areas are chosen in three different locations. Each location was divided to three samples for three types (flat areas, rolling areas and mountainous areas). Each area is about one km square), which distributed in the above locations in Fig.1. Also, Figure (3), Figure (4), Figure (5) and Figure (6) are shown these areas in detail.

V. TERRAIN TYPES:

The terrain is classified into many types of flat surface (smooth) to very rough surface (mountainous). It is very important to classify the terrain before processing the DEM. Terrain surface may be classified using relief characteristics and average slopes beside relief. The terrain classification is done according to some of classification methods which have indications of terrain types. This research work depends on the Roughness Factor Method to classify the terrain types [1]. The roughness factor depends on computing the average slope within a certain circle with an assumed radius. points has roughness factor less than 5 % and so on, until the percentage roughness factor of accumulative After that, it can be calculated the average slope for each point or circle.

The roughness factor is computed using equation (1)[4].

This procedure is repeated to all points data for the study area. Then, each circle has a certain R.F. The percentage, of the points have roughness factor less than 1%, will be computed. Also, the percentage, of the less than 100 %. The next curve is designed and determined the type of terrain type as shown in fig. 2. and according to the table-II[8].

$$R.F = \frac{\Delta Z_{ave}}{\Delta d_{ave}} 100\% \tag{1}$$

Table- II: Maximum permissible grades for highways (%) [9].

Type	slope %
Flat (smooth)	Less than 5
Rolling (undulant)	from5 to12
Mountainous (very rough)	More than12

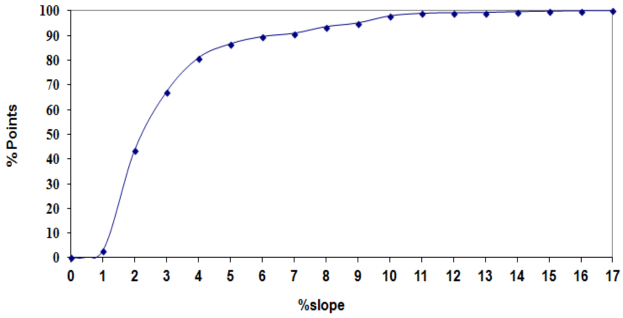

Fig. 2. Percentage of Slope and Its Corresponding Points

Fig. 3a. Three Flat Areas (F1, F2 and F3)

Fig. 3-b. Three Rolling Areas (R1, R2 and R3)

Fig. 3-c. Three Mountainous Areas (M1, M2 and M3)

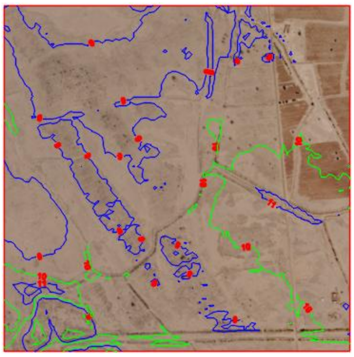

Fig. 4-a. F1 contour interval = 1 m

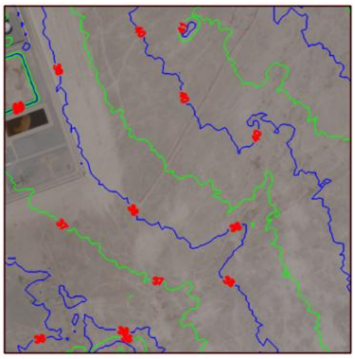

Fig. 4-b. F2 contour interval = 1 m

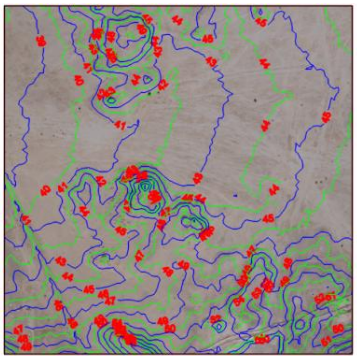

Fig. 4-c. F3 contour interval = 1 m

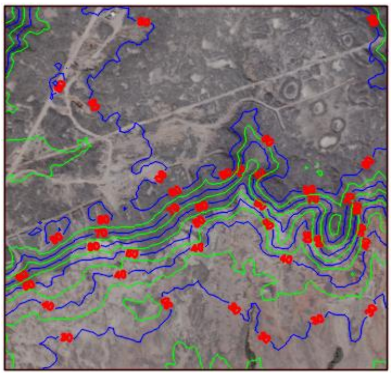

Fig. 5-a. R1 contour interval = 5 m

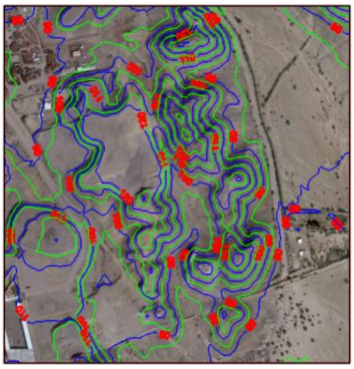

Fig. 5-b. R2 contour interval = 5 m

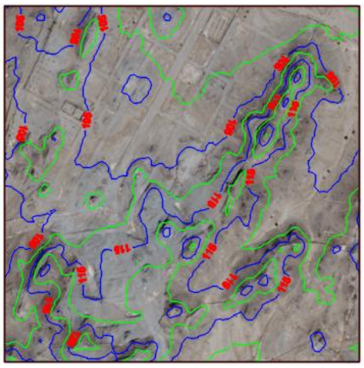

Fig. 5-c. R3 contour interval = 5 m

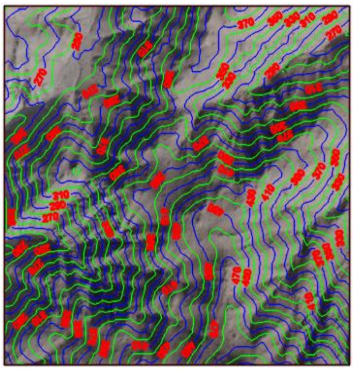

Fig. 6-a. M1 contour interval = 10 m

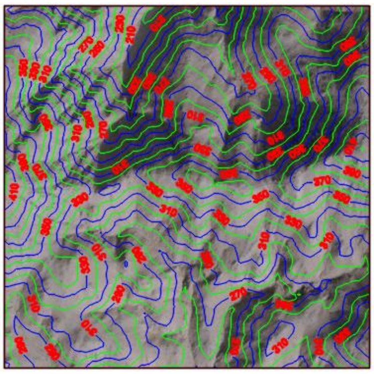

Fig. 6-b. M2 contour interval = 10 m

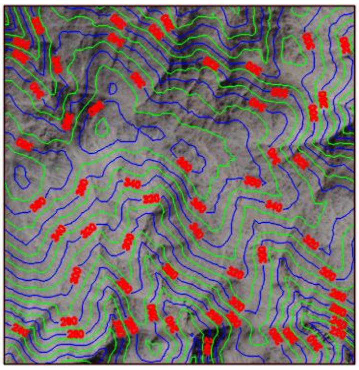

Fig. 6-c. M3 contour interval = 10 m

The figures (4,5, and 6) are illustrated the contour maps for each area for the original LADIR data with grid space 5m. All this data is classified into three categories after applying the terrain classification method. So, the contour maps for each area were produced.

VI. DATA PROCESSING

For both ASTER (30m*30m) and SRTM (90 m*90 m) is transformed and registered related to LIDAR data. The original LIDAR data have a spacing 5m*5m. In order to make a comparison with ASTER and SRTM with respect to the LIDAR data will be divided into grid spacing (30 m*30 m) for ASTRER and (90 m*90 m) for SRTM. For each area of the nine areas mentioned above, the following steps algorithm would be processed:

a. Terrain classification was made using the Roughness Factor mentioned above in section 4.
b. Statistical analysis of elevation values for different terrain type for ASTER and SRTM in table-III and table -IV respectively.

Table-III: statistical analysis of elevation values for ASTER and LIDAR data with grid spacing (30m* 30m) for different area type.

Terrain type	Data source	Z_{max}	Z_{min}	Z_{mean}	Different	RMS
F1	ASTER	13.73	4.37	7.88	9.36	1.54
	LIDAR	11.29	7.65	9.41	3.65	0.59
F2	ASTER	45.00	21.34	32.77	23.66	3.78
	LIDAR	43.10	32.90	38.65	10.20	1.81
F3	ASTER	46.98	22.45	34.64	24.53	5.35
	LIDAR	59.79	37.90	45.12	21.89	3.92
R1	ASTER	81.47	10.00	54.86	71.47	19.48
	LIDAR	85.03	23.13	62.19	61.90	22.19
R2	ASTER	116.00	87.00	100.24	29.00	6.39
	LIDAR	134.00	96.88	109.31	37.25	7.24
R3	ASTER	113.55	70.54	90.53	43.01	10.24
	LIDAR	134.83	74.88	95.33	59.95	13.83
M1	ASTER	504.21	185.84	311.41	318.38	69.70
	LIDAR	513.94	218.39	349.55	295.56	65.17
M2	ASTER	480.10	203.62	313.75	276.48	55.99
	LIDAR	421.82	199.09	308.62	222.72	40.74
M3	ASTER	370.81	196.62	295.40	174.19	42.58
	LIDAR	401.13	193.34	312.28	207.79	44.88

Table IV: statistical analysis of elevation values for SRTM and LIDAR data with grid spacing (90m* 90m) for different area type.

Terrain type	Data source	Z_{max}	Z_{min}	Z_{mean}	Different	RMS
F1	STRM	11.00	10.00	10.01	1.00	0.12
	LIDAR	10.91	7.97	9.40	2.95	0.58
F2	STRM	45.00	37.00	39.96	8.00	1.87
	LIDAR	43.10	33.33	38.63	9.77	1.94
F3	STRM	50.00	39.00	45.18	11.00	2.99
	LIDAR	57.18	38.00	45.21	19.18	4.08
R1	STRM	85.00	28.00	68.00	57.00	17.79
	LIDAR	85.03	23.13	61.52	61.90	22.34
R2	STRM	153.56	83.21	101.22	70.35	11.48
	LIDAR	131.38	74.91	94.90	56.48	13.92
R3	STRM	126.00	97.00	106.34	29.00	8.41
	LIDAR	134.12	97.05	109.22	37.08	7.28
M1	STRM	475.15	244.00	333.86	231.15	53.77
	LIDAR	510.21	221.02	347.98	289.19	66.58
M2	STRM	478.53	196.21	316.31	282.32	60.87
	LIDAR	414.60	202.94	309.35	211.66	42.11
M3	STRM	400.79	199.40	312.59	201.40	44.99
	LIDAR	395.24	200.92	307.74	194.32	46.30

VII. RESULTS, AND ANALYSIS:

The grid level for all nine areas were established (interpolated from LIDAR data (from grid spacing 5m* 5m to 30 m*30 m) to compare it with ASTER data of grid spacing (30m*30m) for the same location (after registration and transformation process.). Also, the previous step is repeated for LIDAR (from grid spacing 5m* 5m to 90 m*90 m) data to compare it with SRTM data of grid spacing (90m*90m) for the same location (after registration and transformation process).

a) The difference in heights in both data sources are computed in each area for each grid point. Table-V illustrates the maximum, minimum, mean and root mean square error (RMS) for the difference of Heights which computed between LIDAR data & ASTER data.

Table-V: Height difference (Maximum, Minimum, Mean, and RMS) between ASTER and LIDAR) for different area types.

Terrain type		Z_{max}	Z_{min}	Z_{mean}	RMS
Name	RMS				
F1	1.54	5.81	-4.40	1.53	1.75
F2	3.78	14.16	-8.10	5.88	3.38
F3	5.35	23.78	-0.13	10.48	4.23
R1	19.48	50.62	-32.08	7.33	13.63
R2	22.19	41.21	-24.30	4.79	15.10
R3	10.24	33.57	-8.97	9.07	7.62
M1	69.70	136.15	-103.25	38.13	63.45
M2	55.99	122.25	-119.66	-5.13	54.60
M3	42.58	106.21	-85.98	16.88	36.13

b) Figures (7, 8, and 9) are illustrated the maximum, minimum, mean and root mean square error (RMS) for the difference of Heights which were computed between LIDAR data & ASTER for each terrain type in separated chart, but figure (10) for three types in the same chart.

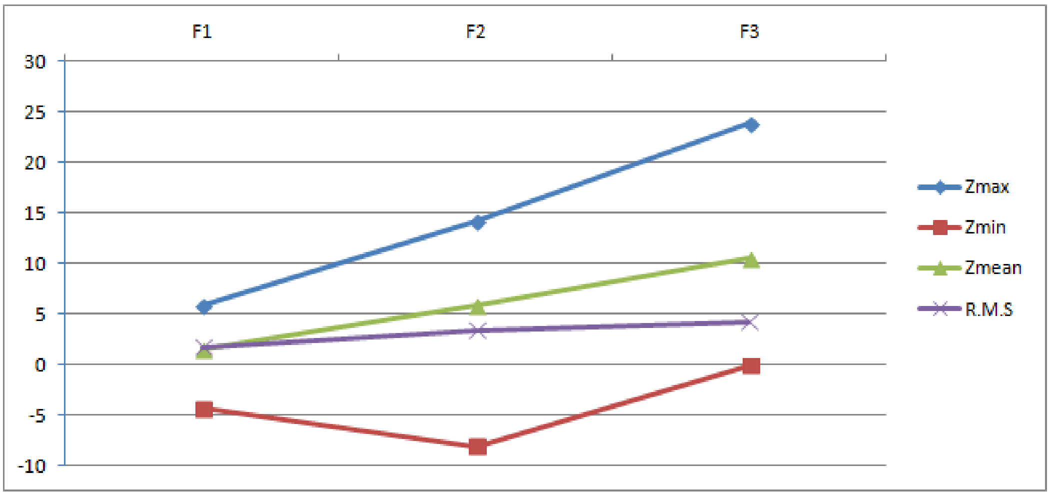

Fig. 7. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for Flat type

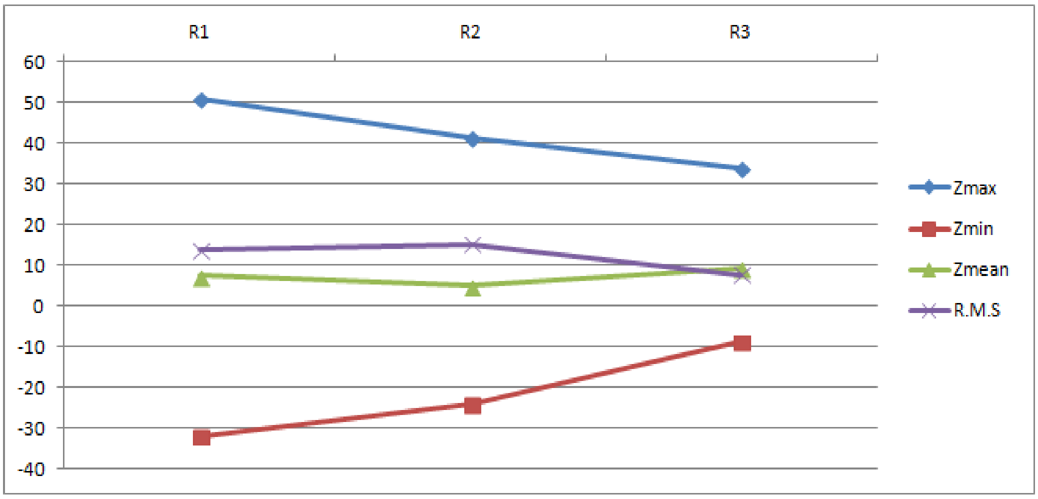

Fig. 8. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for Rolling type

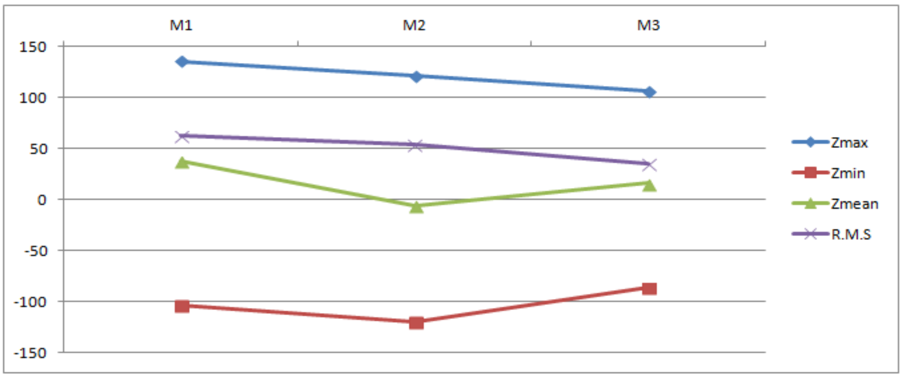

Fig. 9. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for Mountainous type

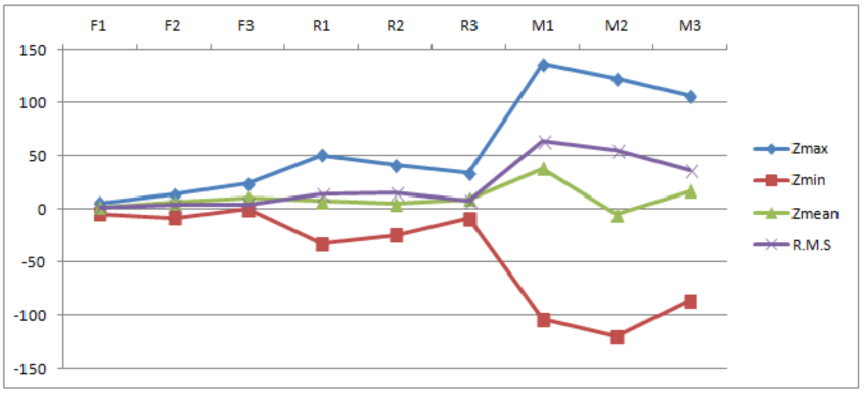

Fig. 10. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for different terrain types

c) Table (VI) illustrates the maximum, minimum, mean and root mean square error (RMS) for the difference of Heights which were computed between LIDAR data & SRTM data.

Table-VI: Height difference (Maximum, Minimum, Mean, and RMS) between SRTM and LIDAR) for different area types.

Terrain type		Z_{max}	Z_{min}	Z_{mean}	RMS
Name	RMS				
F1	1.54	0.91	-2.04	-0.62	0.56
F2	3.78	-0.18	-4.67	-1.34	0.70
F3	5.35	9.18	-7.61	0.03	2.74
R1	19.48	40.63	-47.45	-6.49	15.68
R2	22.19	33.09	-58.04	-6.31	12.67
R3	10.24	27.67	-26.40	2.88	9.39
M1	69.70	112.03	-87.57	14.12	40.56
M2	55.99	109.01	-107.95	-6.96	59.48
M3	42.58	103.09	-112.35	-4.84	52.16

d) Figures (11, 12, and 13) are illustrated the maximum, minimum, mean and root mean square error (RMS) for the difference of Heights which were computed between LIDAR data & STRM for each terrain type in separated chart, but figure (14) for three types in the same chart.

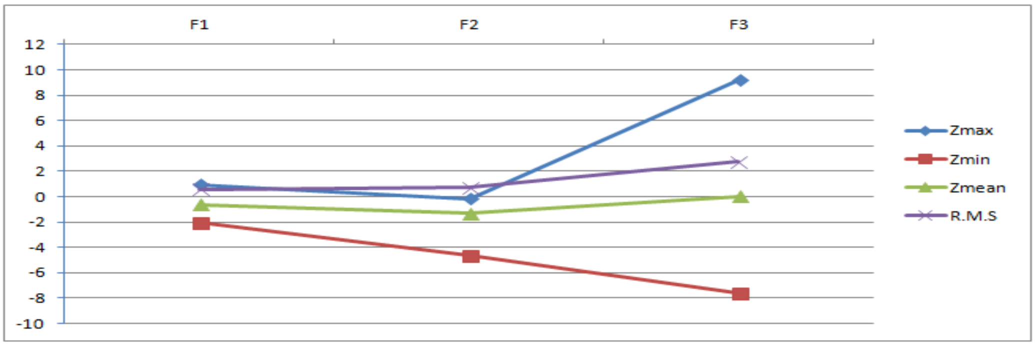

Fig. 11. Height difference (Maximum, Minimum, Mean, and R.M.S) between STRM and LIDAR) for Flat type.

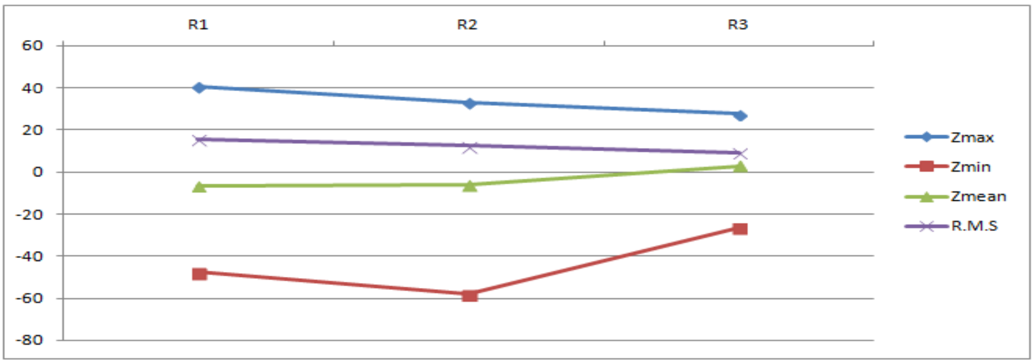

Fig. 12. Height difference (Maximum, Minimum, Mean, and R.M.S) between STRM and LIDAR) for Rolling type.

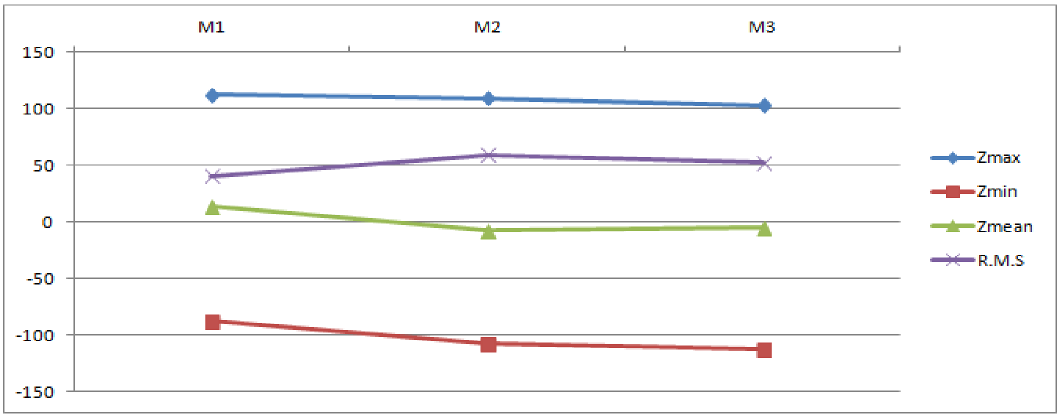

Fig. 13. Height difference (Maximum, Minimum, Mean, and R.M.S) between STRM and LIDAR) for Mountainous type.

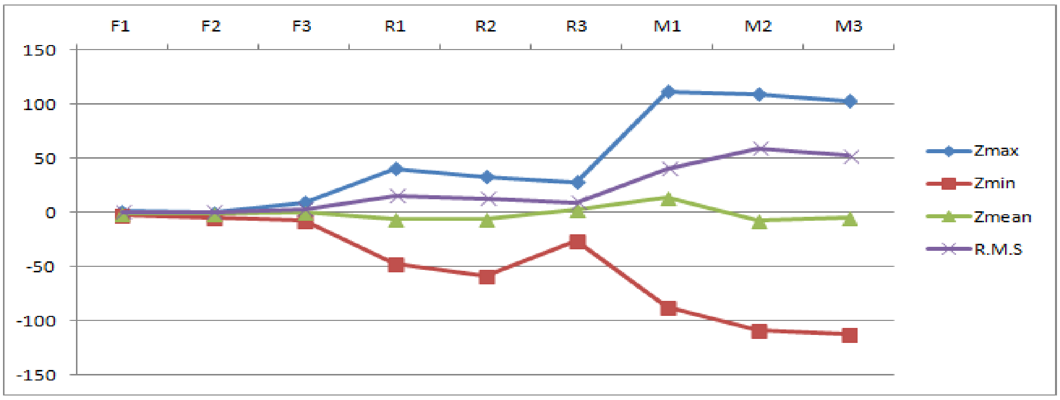

Fig. 14. Height difference (Maximum, Minimum, Mean, and R.M.S) between STRM and LIDAR) for different terrain types.

e) Because the ASTER and SRTM have a systematic error (there is a shift in heights between the LIDAR data and corresponding data from both sources. So, the results in a table (V) for ASTER data and table (VI) for SRTM data are computed again, after removing the shift in heights, on table (VII) and table (VIII) respectively.

Table-VII: Height difference (Maximum, Minimum, Mean, and RMS) between ASTER and LIDAR) for different area type after removing systematic error.

Terrain type		Z_{max}	Z_{min}	Z_{mean}	RMS
Name	RMS				
F1	1.54	4.28	-5.93	0.00	1.07
F2	3.78	8.28	-13.98	0.00	2.08
F3	5.35	13.31	-10.60	0.00	2.48
R1	19.48	43.29	-39.41	0.00	9.85
R2	22.19	36.42	-29.09	0.00	8.43
R3	10.24	24.50	-18.05	0.00	4.49
M1	69.70	98.02	-141.38	0.00	30.83
M2	55.99	127.38	-114.53	0.00	29.92
M3	42.58	89.33	-102.86	0.00	20.06

f) Figures (15, 16, and 17) are illustrated the maximum, minimum, mean and root mean square error (RMS) for the difference of Heights which were computed between LIDAR data & ASTER for each terrain type in separated chart, after removing the systematic error. But figure (18) for three types in same chart.

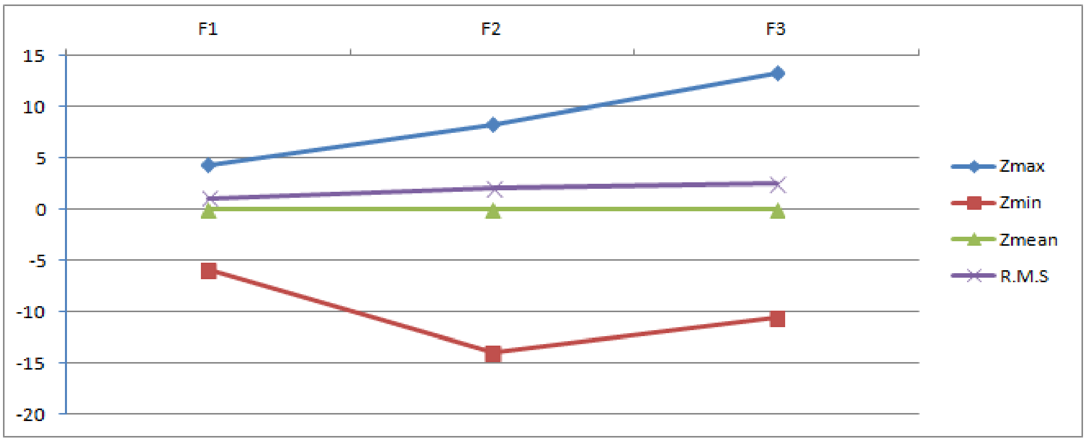

Fig. 15. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for Flat type after removing the systematic error.

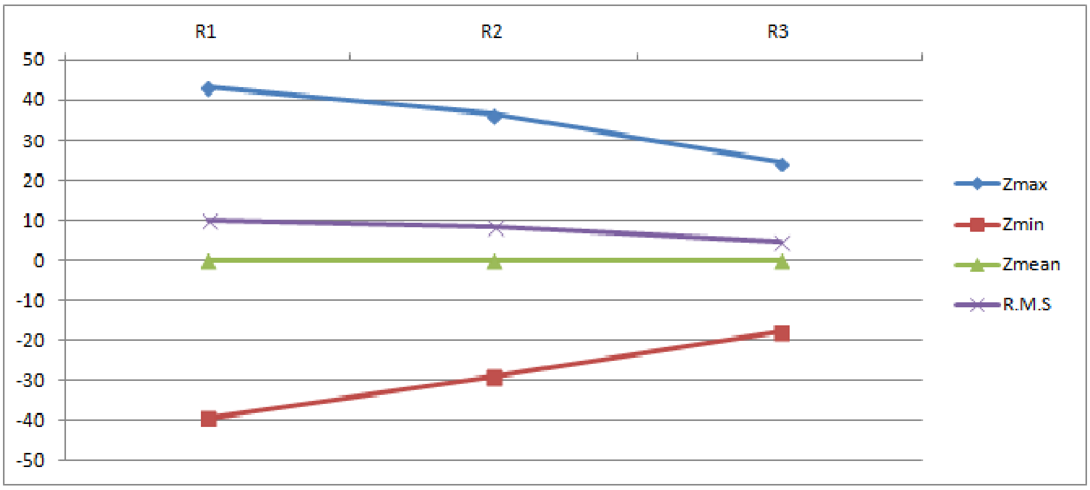

Fig. 16. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for Rolling type after removing the systematic error.

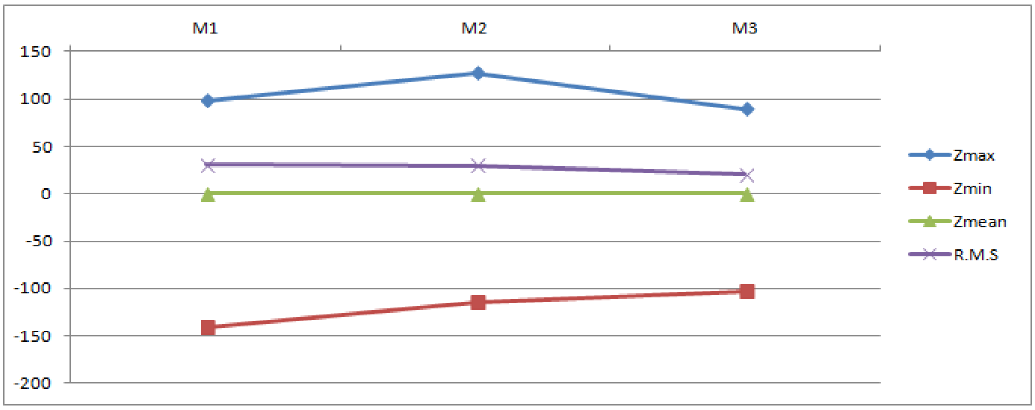

Fig. 17. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for Mountainous type after removing the systematic error.

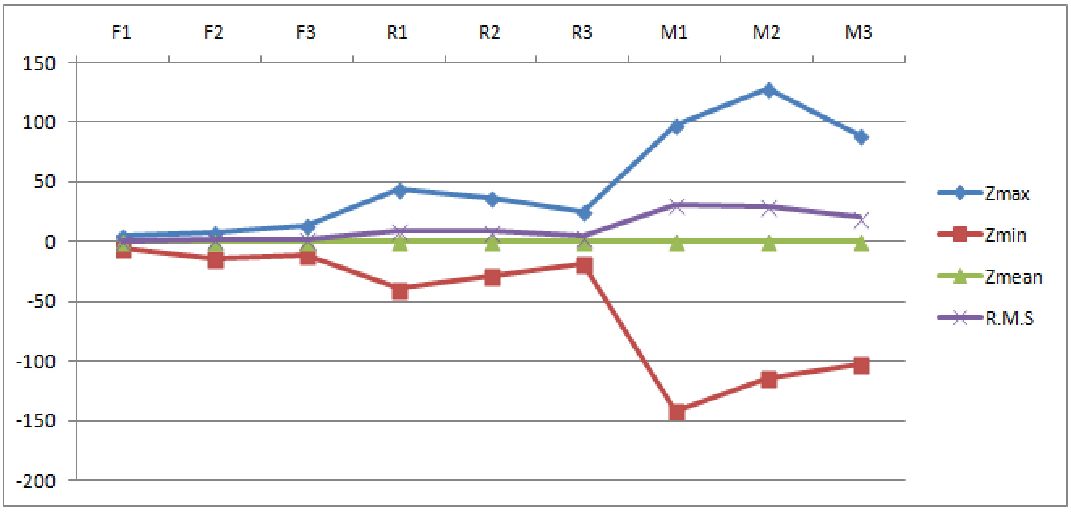

Fig. 18. Height difference (Maximum, Minimum, Mean, and R.M.S) between ASTER and LIDAR) for different terrain types after removing the systematic error.

Table -VIII: Height difference (Maximum, Minimum, Mean, and RMS) between SRTM and LIDAR) for different area type after removing systematic error.

Terrain type		Z_{max}	Z_{min}	Z_{mean}	RMS
Name	RMS				
F1	0.12	1.53	-1.42	0.00	0.35
F2	1.87	1.16	-3.33	0.00	0.51
F3	2.99	9.15	-7.64	0.00	1.72
R1	17.79	47.12	-40.96	0.00	10.56
R2	11.48	39.40	-51.73	0.00	8.46
R3	8.41	24.79	-29.28	0.00	6.46
M1	53.77	97.91	-101.69	0.00	23.49
M2	60.87	115.97	-100.99	0.00	30.21
M3	44.99	107.93	-107.51	0.00	27.80

g) Figures (19, 20, and 21) are illustrated the maximum, minimum, mean and root mean square error (RMS) for the difference of Heights which were computed between LIDAR data & SRTM for each terrain type in separated chart, after removing the systematic error. But figure (22) for three types in same chart.

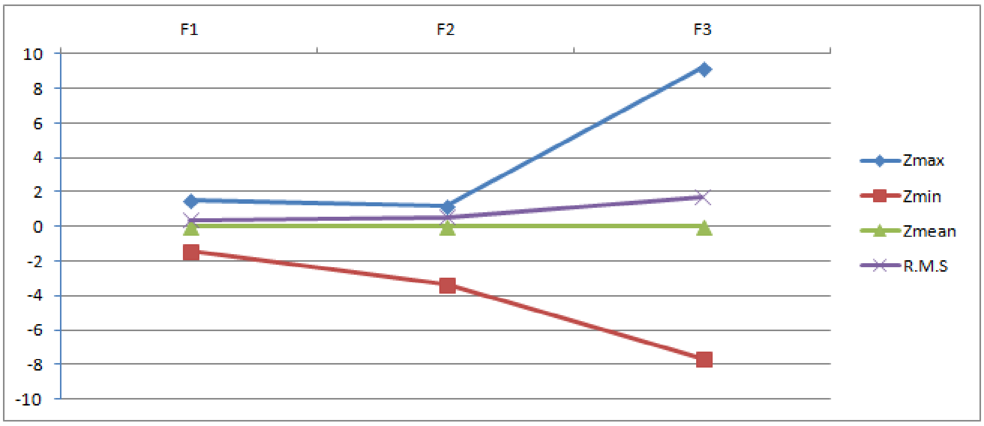

Fig. 19. Height difference (Maximum, Minimum, Mean, and R.M.S) between SRTM and LIDAR) for Flat type after removing the systematic error.

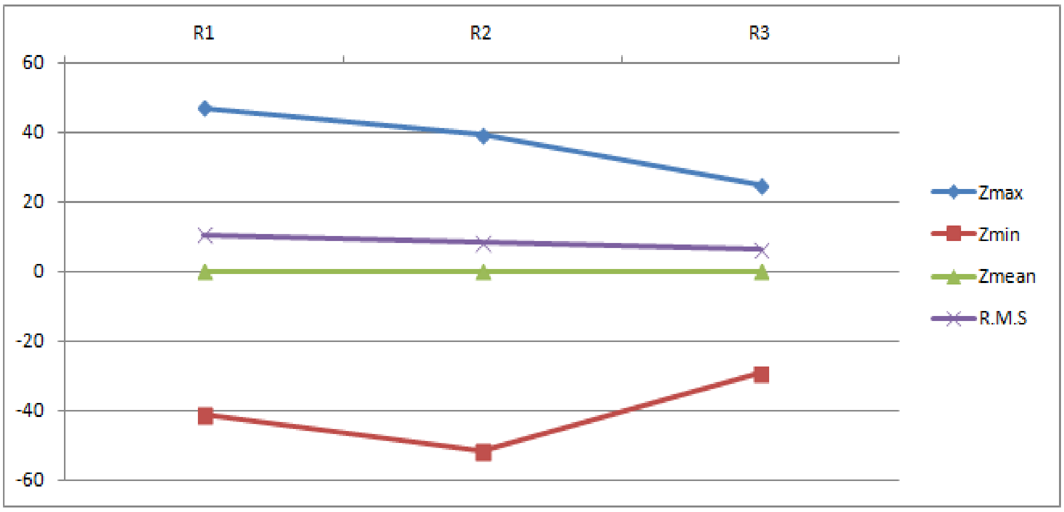

Fig. 20. Height difference (Maximum, Minimum, Mean, and R.M.S) between SRTM and LIDAR) for Rolling type after removing the systematic error.

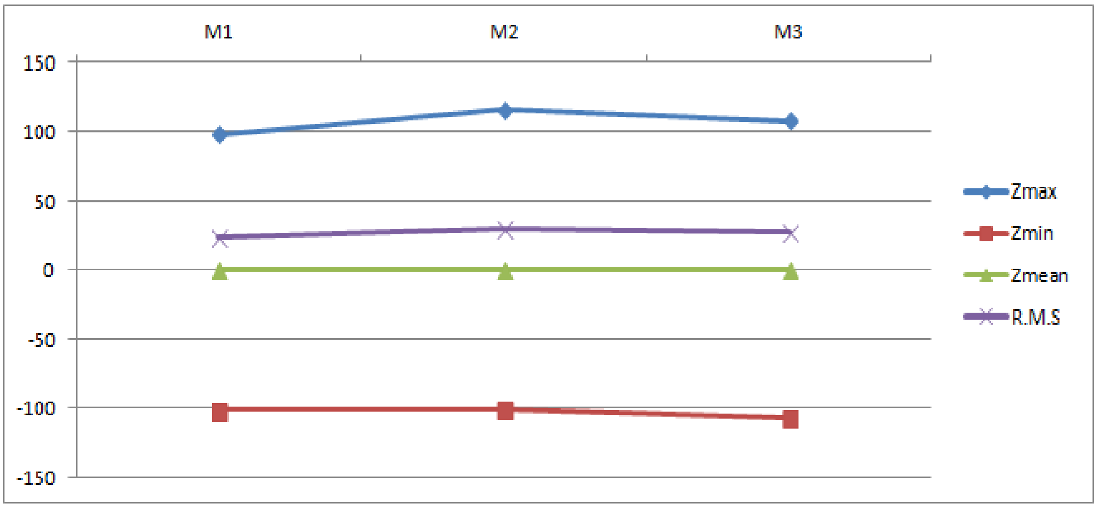

Fig. 21. Height difference (Maximum, Minimum, Mean, and R.M.S) between SRTM and LIDAR) for Mountainous type after removing the systematic error.

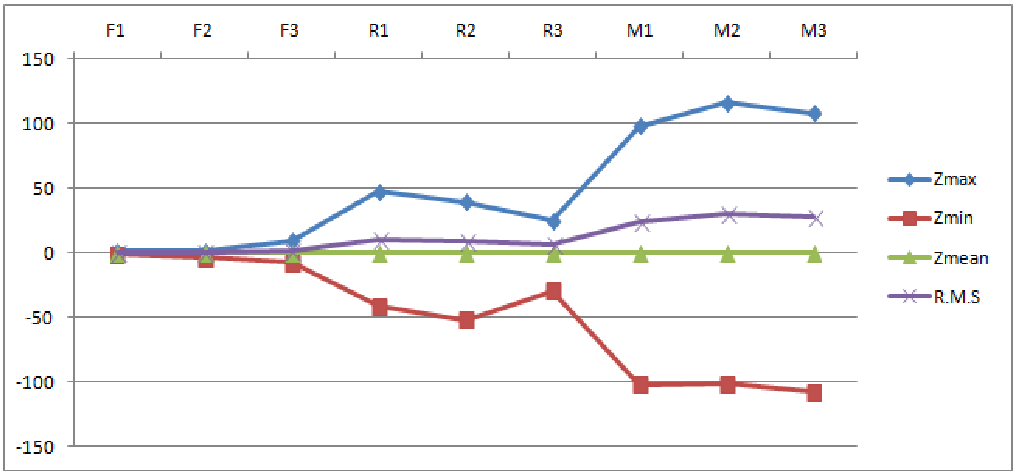

Fig. 22. Height difference (Maximum, Minimum, Mean, and R.M.S) between SRTM and LIDAR) for different terrain types after removing the systematic error.

h) Figure (23) is illustrated the comparative of the root mean square error (RMS) ASTER and SRTM for each terrain type for three terrain types after removing the systematic error.

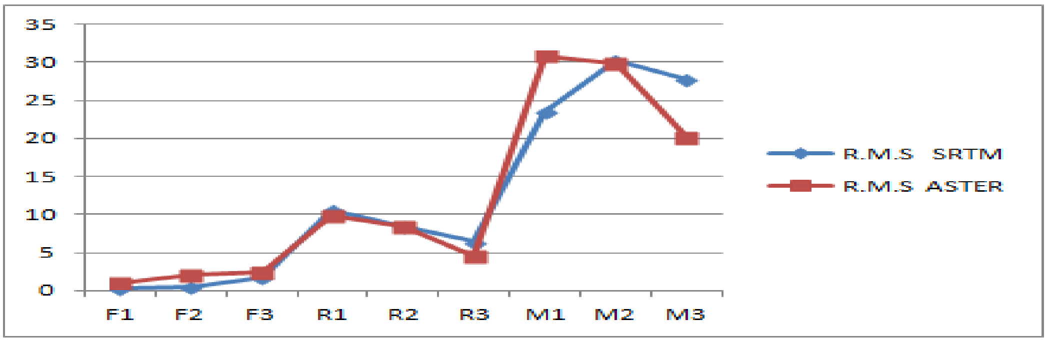

Fig. 23. Comparative RMS between ASTER and SRTM for each terrain type for three terrain types after removing the systematic error.

From the above obtained results for ASTER data in table (7), figures from (2) to (6) and figure from (15) to (18) too, one can notice that, the accuracy of ASTER is an inversely proportional with the roughness factor.

On the other hand, the accuracy of ASTER is decreased from flat to mountainous terrain type. In flat terrain the accuracy is in between round 1 m to about 2.5m, and round 5m to 10 m for rolling terrain. However, it is about 20m to 30 m for mountainous terrain. In this context, by investigation the table (8), figures from (2) to (6) and figure from (19) to (22) for SRTM data, it can be noticed that, the accuracy of SRTM is an inversely proportional with the roughness factor. On other words, the accuracy of SRTM is decreased from flat to mountainous terrain type. In flat terrain, the accuracy is between about 0.5 m to less than 1.8 m, and about 6.5m to10. 5 m for rolling terrain. However, it's about 23m to 30 m for mountainous terrain. Finally, Fig. (23) shows the RMS comparison of ASTER and SRTM of each terrain type. Obviously, for flat terrain, SRTM data accuracy is better than ASTER data accuracy. The accuracy of both sources is almost the same for the rolling terrain. However, for mountainous terrain, ASTER data accuracy is almost better than SRTM data accuracy.

VIII. CONCLUSION:

Developing countries have lack of suitable height data which is one of the main problems in these countries. So, in this research, the two free global GDEM; (ASTER and SRTM) was checked out with respect to LIDAR data. After the removal of systematic errors, from both source and the obtained results as mentioned before the following conclusion can be summarized:

1) ASTER and SRTM data have an accuracy inversely proportional with the roughness factor.
2) The accuracy of ASTER data is between about 1 m to about 2.5m, for flat terrain.
3) The accuracy of ASTER data is between about 5m to10 m for rolling terrain.
4) The accuracy of ASTER data is between about about 20m to 30 m for mountainous terrain.
5) The accuracy of SRTM data is between about 0.5 m to less than 1.8, for flat terrain.
6) The accuracy of SRTM data is between about 6.5m to10.5 m for rolling terrain.
7) The accuracy of SRTM data is between about about 23m to 30 m m for mountainous terrain.

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8) For flat terrain the accuracy of SRTM data is less than the accuracy of ASTER data.
9) For rolling terrain the accuracy of SRTM data is approximately the same of ASTER data.
10) For mountainous terrain the accuracy of ASTER data is almost better than the accuracy of SRTM data.

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