Studying the effect of distortion in basic map elements for the degree of spatial accuracy of Gaza Strip maps

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1 author:

M. A. El-Hallaq
Islamic University of Gaza

STUDYING THE EFFECT OF DISTORTION IN BASIC MAP ELEMENTS FOR THE DEGREE OF SPATIAL ACCURACY OF GAZA STRIP MAPS

Maher A. El-Hallaq

Assistant professor, Civil Engineering Department, IUG, Palestine, mhallaq@iugaza.edu.ps

ABSTRACT:
The used coordinate system in Palestine was established by the British Military Survey in 1923. This system is based on "Palestine 1923" datum that corresponds to "Clarke 1880" spheroid and a transverse cylindrical projection called "Cassini". All maps in Palestine are produced and analyzed according to this coordinate system. With the wide range use of the GPS technology in Palestine as well as the large development in Geographic Information System applications, maps may be produced with different coordinate systems. This matter becomes more complicated since maps are produced by external agencies like Israeli companies or donors, etc. This leads to cause a spatial change while comparing or combining maps from different sources. Thus, it is necessary to study the reliability degree of maps from different sources to verify the effect of change in a map coordinate system to its spatial accuracy. This research aims to investigate the degree of spatial change occurred in map features due to a change in some basic map elements, such as map datum and/or projection in addition to a change in map scale and map included area, while combining data from different sources. Three case studies are performed to analyze the planimetric accuracy of various maps in Palestine, and mainly in the Gaza Strip. The maps include Rafah City, Gaza City and a map showing the border of the Gaza Strip itself. Selection is chosen on the basis of different constituting area, different projection and/or datum, and different scale.

KEYWORDS: Maps, Gaza Strip, Spatial Accuracy, Datum and Projection Change

1. BACKGROUND

The map is a powerful way of presenting the information held within spatially referenced data. It is also a universal medium for communication, easily understood and appreciated by most people, regardless of language or culture. Most GIS software packages make producing basic maps easy as it is a core part of their functionality. This means that almost as soon as the data are in a GIS format, the researchers are able to explore such data through maps. The maps can be refined and re-drawn multiple times as part of the research process, giving the researcher the ability to gain a thorough understanding of the spatial patterns the data contain. High quality maps always contain essential map elements that help the reader efficiently and quickly understand and correctly interpret the information displayed. The main types of map elements include:

1. Title	2. Legend	3. Scale
4. North arrow	5. Neatline	6. Coordinate system
7. Map author	8. Date of production	9. Body of the map
10. Locator maps	11. Inset maps	12. Indexed maps
13. Graticule	14. Credits	15. Logos

The above elements importance may vary from map to another. Major map elements can be categorized as: common elements, context sensitive elements and effective communication elements. Common elements can be found on the great majority of map projects such as scale, legend, north arrow and source. Context sensitive elements are related to the nature of the information being displayed as title, coordinate system (projection and datum), scale, north arrow, legend and credits. Effective communication elements are used to improve the readability of the map as locator maps and insets [1]. From a surveying point of view, the principal main elements of the map in our case are their referenced coordinate system (projection and datum), scale and area included which may seriously affect the spatial identification of map features. Therefore, our focus concentrates on these elements.

2. PROBLEM STATEMENT

Many countries have upgraded their old coordinate systems that refer to the 19th century or the beginning of the 20th century. They have switched to newer and more accurate spheroids like WGS84, which is being the base for determining location in Global Positioning System GPS, or use another projection as Universal Transverse Mercator UTM. Particularly in Palestine, the used coordinate system was established by the British Military Survey in 1923. This system is based on "Palestine 1923" datum that corresponds to "Clarke 1880" spheroid and a transverse cylindrical projection called "Cassini". All maps in Palestine are produced and analyzed according to this coordinate system. With the wide range use of the GPS technology in Palestine as well as the large development in Geographic Information System applications, maps are produced with different coordinate systems. The matter becomes more complicated where maps are produced by external agencies like Israeli companies or donors, etc. This leads to cause a spatial change while comparing or combining maps from different sources. Thus, it is necessary to study the reliability degree of maps from different sources to verify the effect of change in a map coordinate system to its spatial accuracy. This can help in tracing and examining error propagation in maps due to different sources, disputing and resolving boundary conflicts and extracting reliable geometric information from combining data from different sources.

3. RESEARCH AIM

This research aims to investigate the degree of spatial change (distortion) occurred in map features due to a change in some basic map elements, such as map datum and/or projection in addition to a change in map scale and map included area, while combining data from different sources of Gaza Strip maps.

4. METHODOLOGY

The following stages are taken into consideration while conducting this research:

- Literature review stage regarding this subject.
- Data collection stage of map samples that are useful in our case. Three map samples (case studies) are considered.
- Map transformation stage of each map sample. A WGS84-UTM coordinate system will be the reference and each map is then re-projected to different datum, different projection and different both datum and projection using ArcGIS 9.3 Software.
- Map matching stage of each projected map sample with the reference map taking map scale and map included area into account. For this purpose, a friendly Graphical User Interface (GUI), named "Map Correlation", is introduced by the author to facilitate comparing maps [2 – 4]. It is very easy to use and contains simple icons to help executing tasks quickly and based on a template image matching technique. It is capable to import, filter, transform, overly, export and correlate maps. Correlation can be expressed in a scalar coefficient or in a correlation matrix format in addition to a correlation contour plot to show places of spatial changes (distortions).
- Analysis stage is performed for each map sample to measure the effect of change of map datum, map projection, both, map scale and map included area on the planimetric accuracy.
- Conclusion stage

5. CASE STUDIES

Three case studies are performed to analyze the planimetric accuracy of various maps in Palestine, and mainly in the Gaza Strip. The maps include Rafah City, Gaza City and a map showing the border of the Gaza Strip itself. Selection is chosen on the basis of different constituting area, different projection or datum or both, and different scale. Results are accompanied by some focus on samples comparison. A thoroughly discussion of the previous analysis is made to explore and comment on things that can be detected. The layout of the three case studies is shown in Figure (1).

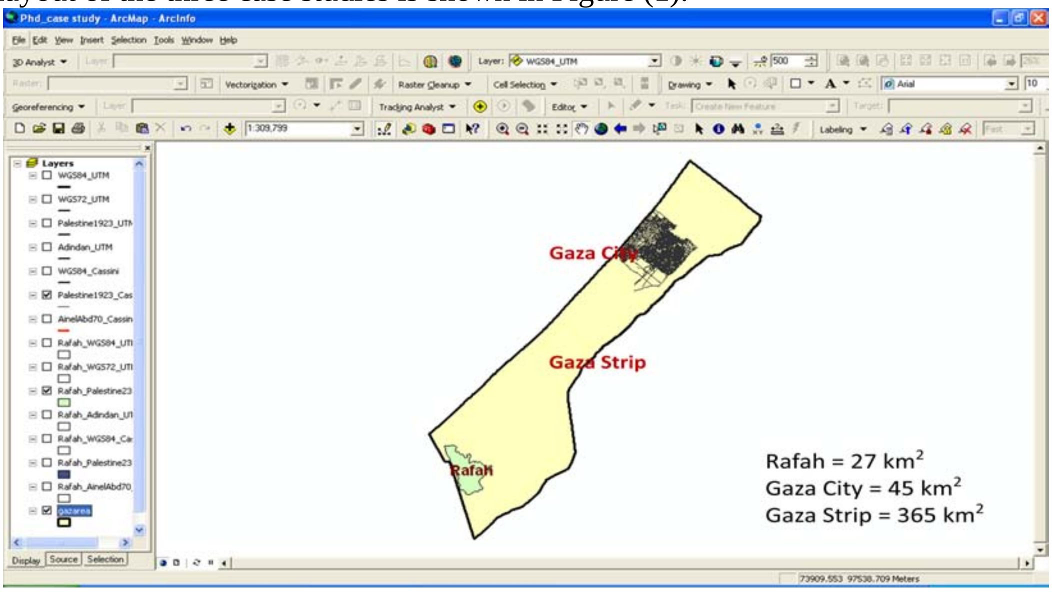

Figure (1): The layout of the three case study maps.

5.1 Case Study One: Gaza Strip

The current case study discusses the effect of the above mentioned factors on the magnitude of correlation and consequently the similarity between maps of the Gaza Strip. Gaza Strip boundary map - with a base WGS84 datum and a base UTM projection - is projected using ArcGIS 9.3 software to maps with different datum, different projection and different both datum and projection. The output maps are then exported to images at different scales. Images are next correlated using "Map Correlation". The results of correlation coefficients are shown in Table (1). Figure (2) shows a layout view of two maps of the Gaza Strip case study where the dark marked is the base map (Datum: WGS84, Projection: UTM) and the light marked is one of the projected maps (Datum: Palestine 1923, Projection: Cassini). The layout view is at a 1:5,000 map scale. It is visually apparent to any observer that there is a large amount of spatial change occurred between the two map images at this scale as both datum and projection are changed. The magnitude of correlation as shown in Table (1) equals 0.199 which agree with the first visual inspection. Nearly, one fifth of the border lines are being matched. For some projected maps, a change in location appears quickly at small scales. On the other hand, it needs being closer to detail (i.e. larger scales) in order to be slightly noticed for others. This is clear when changes are only on the map projection from the considered base reference map. Another sample is a comparison using "Map Correlation" between the reference map and the projected map (Datum: WGS72, Projection: UTM) is illustrated in Figure (3).

Table (1): Correlation coefficients of the Gaza Strip case -study maps

	Change in Projection		**Change in Datum**		**Change in both**	
Datum **Projection**	**WGS84 Cassini**	**WGS84 PDC_Mercator**	**WGS72 UTM**	**Adindan UTM**	**GCS Palestine23**	**Palestine Grid**
1:300,000	1.000	1.000	0.911	0.785	0.716	0.731
1:250,000	1.000	1.000	0.900	0.760	0.645	0.729
1:100,000	1.000	1.000	0.773	0.597	0.564	0.578
1:50,000	0.983	0.992	0.762	0.519	0.470	0.502
1:5,000	0.947	0.963	0.360	0.236	0.143	**0.199**

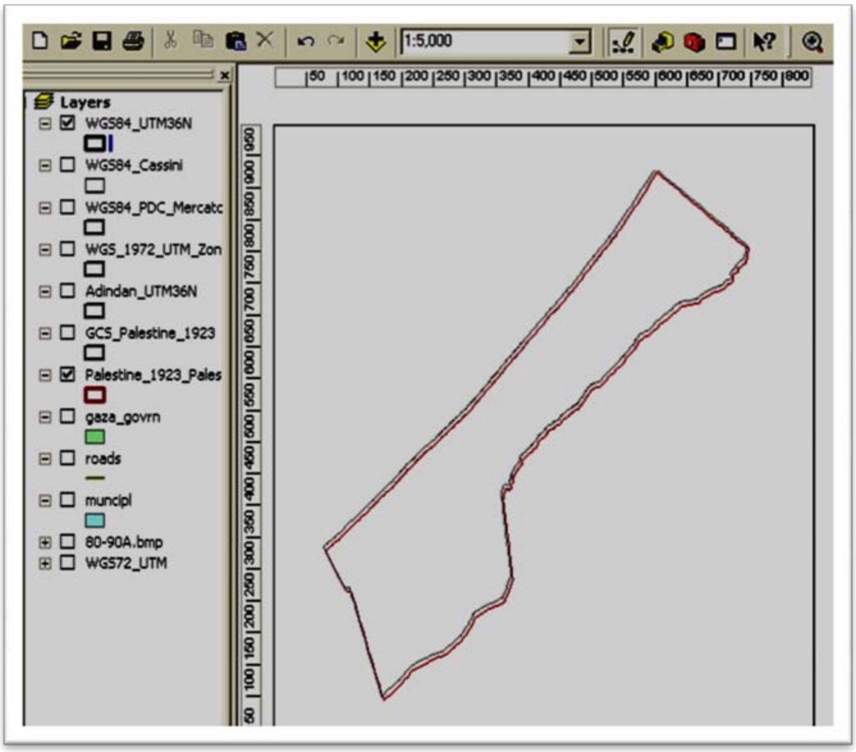

Figure (2): Layout view between two maps of the Gaza Strip case study in ArcMap.

Actually, a spatial change only in the map datum here is chosen to quantify its effect on correlation. The correlation coefficient between them reaches to 0.90. A reduction of 10% is as a result of the transfer between datum (WGS72 instead of WGS84) appears at a small scale 1:250,000.

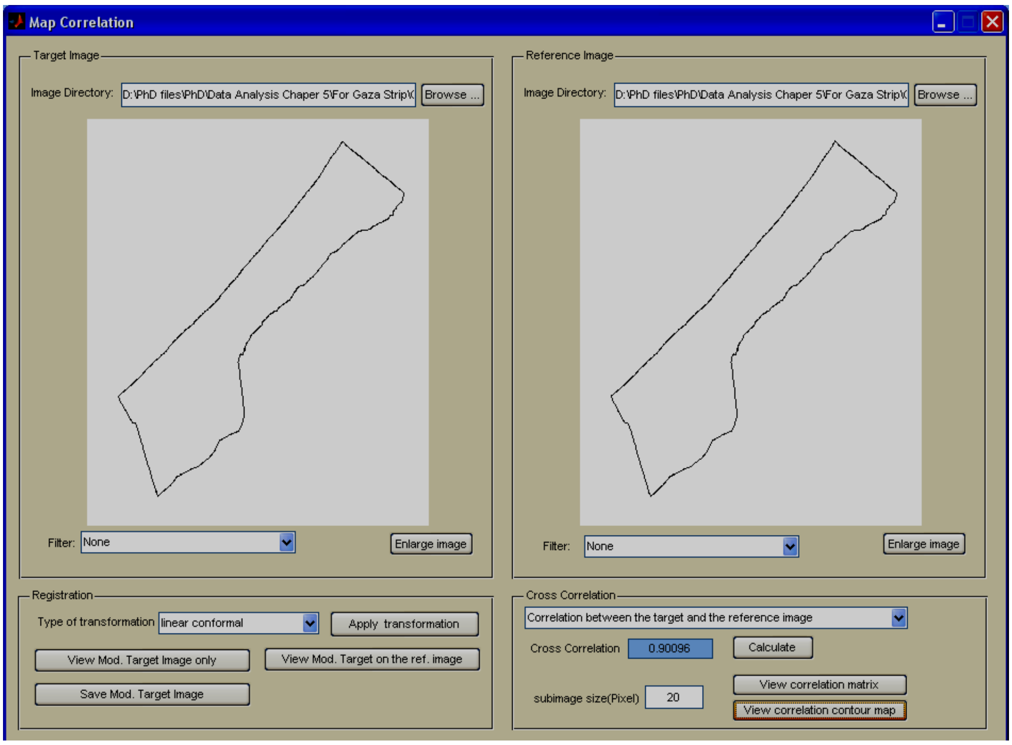

Figure (3): Sample comparison between two maps of Gaza Strip using "Map Correlation".

Whenever a small window size is considered, the more accurate result but a large matrix size is obtained. The correlation matrix of the sample at 60 pixel window size is as follows:

1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9138	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8210	0.8303	1.0000	0.9472
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8610	1.0000	1.0000	0.8649
1.0000	1.0000	1.0000	1.0000	1.0000	0.8777	1.0000	0.9204	0.9254	0.9765
1.0000	1.0000	1.0000	1.0000	0.8877	0.7588	0.8554	0.9214	1.0000	1.0000
1.0000	1.0000	1.0000	0.9070	0.9118	0.9241	0.8945	1.0000	1.0000	1.0000
1.0000	1.0000	0.8923	0.9402	0.8638	0.8875	1.0000	1.0000	1.0000	1.0000
1.0000	0.9166	0.8811	1.0000	0.8671	1.0000	1.0000	1.0000	1.0000	1.0000
0.7769	0.9490	1.0000	1.0000	0.9224	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	0.7767	1.0000	1.0000	0.9403	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	0.9036	0.9759	0.9602	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	0.8086	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Figure (4) below shows the correlation contour plot of the compared maps of the sample. It highlights the places where correlation is minimum or maximum.

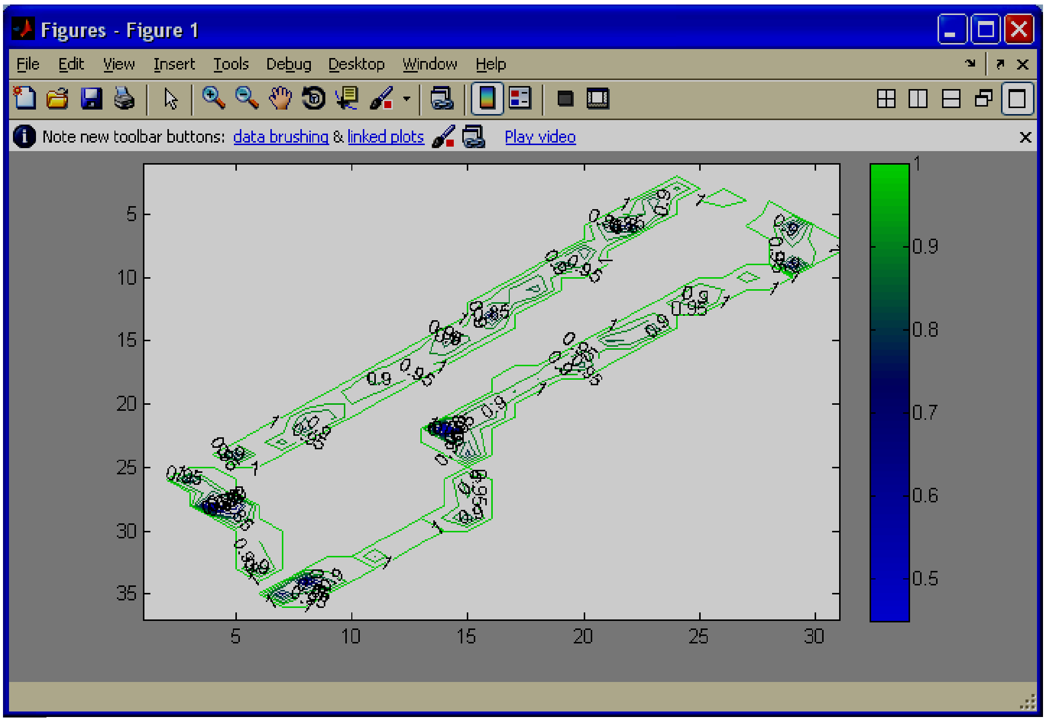

Figure (4): Contour plot of the previous sample at 60 pixel window size.

5.2 Case Study Two: Gaza City

Similarly as made in the Gaza Strip case study, a map shows the network of Gaza City roads with a reference (WGS84, UTM) is reprojected several times using ArcMap Software. Once either the projection or the datum is changed and another both the projection and datum are changed. The exported images are next correlated with the reference image using "Map Correlation". Results obtained are tabulated in Table (2).

Table (2): Correlation coefficients of Gaza City case-study maps

Datum / Projection	Projection change	Change in map Datum			Change in both	
	WGS84 Cassini	Palestine 1923 UTM	WGS72 UTM	Adindan UTM	Palestine 23 Cassini	AinelAbd 70 Cassini
1:250,000	1.000	0.876	0.871	0.744	0.735	0.687
1:100,000	1.000	0.821	0.807	0.653	0.621	0.524
1:50,000	1.000	0.411	0.660	0.456	0.411	0.383
1:5,000	1.000	0.097	0.106	0.110	0.097	0.098

It should be noticed that the current case study maps contain more detail than other case studies. Figure (5) shows a layout view between the reference map (WGS84, UTM) and (AinelAbd 70, Cassini) map. In this case study sample, a spatial change in both the map datum and projection is marked. The correlation coefficient is measured as 0.383 at a scale 1:50,000.

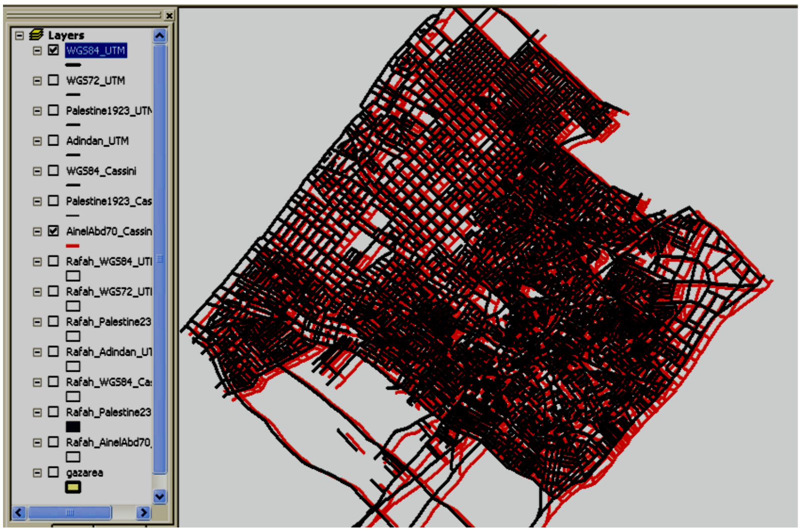

Figure (5): A layout view between two maps of Gaza City case-study.

5.3 Case Study Three: Rafah City

This case study includes maps of Rafah City projected, as the previous case study maps, to different datum and/or projection. The reference map is also with WGS84 Datum and UTM projection. All projected maps are correlated with the reference map and correlation results are given in Table (3). The selected sample in this case study is chosen to consider a spatial change in the map projection only. For this purpose, the reference map (Datum: WGS84, Projection: UTM) is to be correlated with the projected map (Datum: WGS84, Projection: Cassini) at 1:5000 map scale.

Table (3): Correlation coefficients of Rafah City case-study maps

	Projection change	Change in map Datum			Change in both	
Datum **Projection**	**WGS84 Cassini**	**Palestine 1923 UTM**	**WGS72 UTM**	**Adindan UTM**	**Palestine 23 Cassini**	**AinelAbd 70 Cassini**
1:250,000	1.000	0.973	0.895	0.804	0.757	0.697
1:100,000	1.000	0.930	0.818	0.671	0.659	0.563
1:50,000	1.000	0.800	0.792	0.585	0.612	0.522
1:5,000	1.000	0.689	0.424	0.292	0.251	0.237

The correlation coefficient by "Map Correlation" equals 1.0 and that means full matching. To see if this statistical basis agrees with the visualization of matching in ArcMap 9.2. Figure (6) shows a layout of the two maps at a 1: 30,000 scale. The reference scale is dark marked while the projected is red in the legend. It is obvious that they are identical and there is no change noticed. Sailing to large scales zoom, there is still no change until reaching to scales approximately 1:30 or larger. See Figure (7). Therefore, they seem to be identical at a 1:5,000 scale and the correlation value is 1.0.

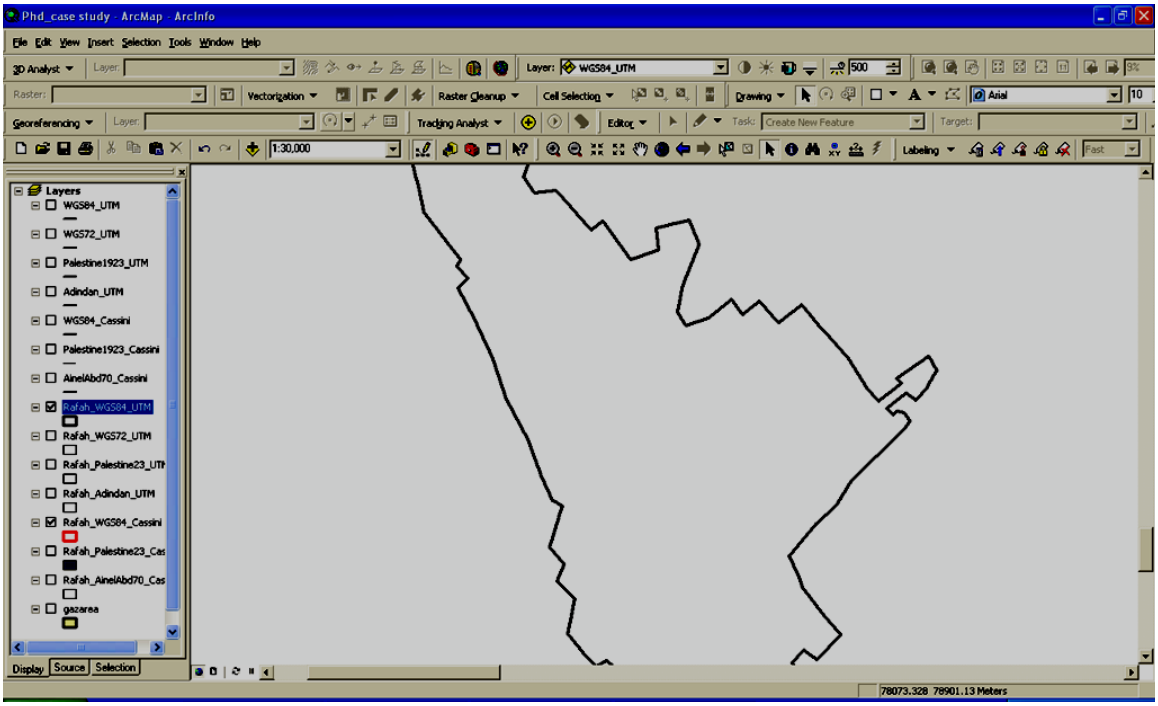

Figure (6): Layout view of Rafah sample maps at 1:30000 scale in ArcMap.

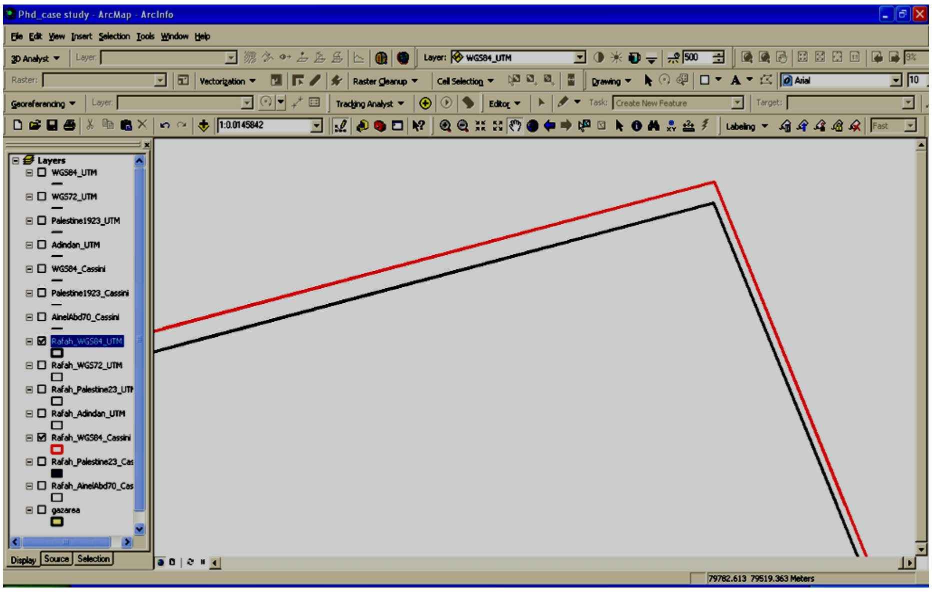

Figure (7): Layout view of Rafah sample maps at 1:30 map scale in ArcMap.

5.4 Case Studies Discussion

After performing the three case studies regarding the Gaza Strip, Gaza City and Rafah maps, some indications can be concluded from the analysis results towards the effect on correlation by the spatial change of maps in their included area, projection and/or datum in addition to map scale.

A. The effect of change in map included area

The ascending order of the case studies according to their map included area is Rafah, Gaza City and the Gaza Strip maps. Table (4) summarizes the correlation results in Table (1), Table (2) and Table (3) for Rafah, Gaza City and Gaza Strip cases respectively.

Table (4): The effect of map included area on map matching.

Datum / Projection	WGS84 Cassini	Palestine 1923 UTM	WGS72 UTM	Adindan UTM	Palestine 23 Cassini	AinelAbd 70 Cassini
1:250,000	*1.000*	*0.973*	*0.895*	*0.804*	*0.757*	*0.697*
	1.000	0.876	0.871	0.744	0.735	0.687
	1.000	**-**	**0.900**	**0.760**	**0.729**	**-**
1:100,000	*1.000*	*0.930*	*0.818*	*0.671*	*0.659*	*0.563*
	1.000	0.821	0.807	0.653	0.621	0.524
	1.000	**-**	**0.773**	**0.597**	**0.578**	**-**
1:50,000	*1.000*	*0.800*	*0.792*	*0.585*	*0.612*	*0.522*
	1.000	0.411	0.660	0.456	0.411	0.383
	0.983	**-**	**0.762**	**0.519**	**0.502**	**-**
1:5,000	*1.000*	*0.689*	*0.424*	*0.292*	*0.251*	*0.237*
	1.000	0.097	0.106	0.110	0.097	0.098
	0.947	**-**	**0.360**	**0.236**	**0.199**	**-**

Italic typed correlation values correspond to that of Rafah maps and normal ones for Gaza City maps, while bold typed related to Gaza Strip maps. Dashed values indicate no correlation action is made.

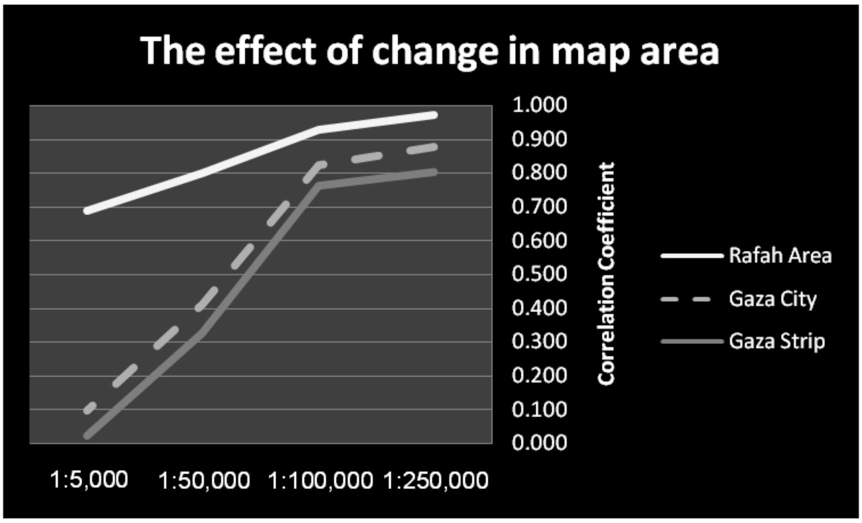

Figure (8): The effect of change of map included area in map matching.

Keeping in mind that Rafah area constitutes 27 km^2, Gaza City is 45 km^2 while Gaza Strip area is 365 km^2. Obviously, correlation values for Rafah maps are greater than their counterparts of Gaza City maps, Figure (8). This implies that the effect on correlation due to the change in map considered area has high significance for higher map areas in spite of the change in datum and projections. High differences are especially noticed whenever map scales being large. Fore example, as comparing the reference map with Palestine 1923 – UTM map, the difference in the correlation value equals nearly 10% (0.973 – 0.876) at 1:250,000 scale. It is 40% (0.800 – 0.410) at 1:50,000 and 60% (0.689 – 0.097) at 1:5,000.

B. The effect on change in map scale

To examine the effect of this factor on correlation, maps are correlated at small scales as 1:250,000, medium scales as 1:50,000 and large scales as 1:5,000. Going to further large scales is recommended but at the same time requires a very high memory size especially for that of large map included area. In this case, special computers that can support highly detailed graphics and handle complicated analysis are preferred for use. Referring to Table (1) to Table (3), it is concluded that correlation values start decreasing as we move to large scales. For example, noticing the correlation of Rafah maps for WGS72 - UTM with the reference system at different scales, Figure (9). It is 0.895 at 1:250,000, 0.792 at 1:50,000 and 0.424 at a 1:5,000 map scale. Distortion increases whenever we move to larger scales. This is simple because we are being close to detail in maps with large scales.

C. The effect of change in map projection

Table (5.6) outlines the correlation values of the case studies while comparing the reference map (WGS84, UTM) with the projected map (WGS84, Cassini). Projection factor here is only changed. The values indicate less effect on correlation magnitudes by the projection keeping in mind that we consider relatively small areas (maximum area case equals 365 square kilometers). For an area like a continent, distortion can be noticeably measured even for small scales. Indeed, Cassini is considered one of the UTM families since both are based on transverse cylindrical projections and nearly have similar transformation parameters.

Table (5): Effect on correlation of the projection change in the case studies

Datum Projection	WGS84 Cassini Rafah maps	WGS84 Cassini Gaza City maps	WGS84 Cassini The Gaza Strip maps
1:250,000	**1.000**	**1.000**	1.000
1:100,000	**1.000**	**1.000**	1.000
1:50,000	**1.000**	**1.000**	0.983
1:5,000	**1.000**	**1.000**	0.947

Figure (9) shows the correlation coefficients obtained when comparing maps of Rafah, Gaza City, and the Gaza Strip in the projected form (WGS84 – Cassini) with the reference form (WGS84 – UTM). At small scales, the effect is negligible and thus coefficients equal 1.0 but for large map areas and very large scales, changes are slightly appeared. Fore example, the correlation coefficient is 0.983 for the Gaza Strip case at scale 1:50,000. At this scale, no change is observed for the other case studies. For more illustrations, refer to Figure (6) and Figure (7). Thus, the effect of change in a map projection while comparing two maps of an area can be neglected in case we deal with maps of a small area and at a small scale.

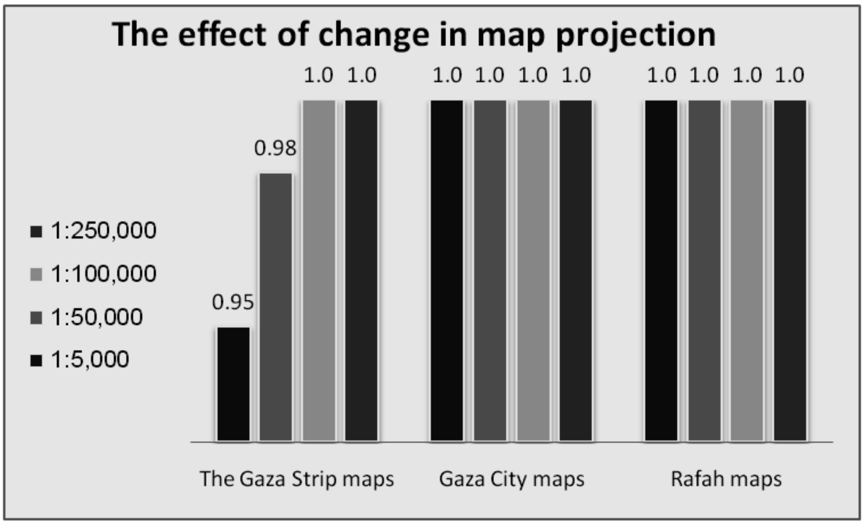

Figure (9): The effect of change of map projection in map matching.

D. The effect of change in map datum

Exploring again Table (1) to Table (3), measureable changes began to appear compared with the effect of projection change even at small scales. This effect becomes considerable at larger scales, see Figure (10). For example, the correlation coefficient of Rafah maps equals 0.895 when changing WGS84 with WGS72 at a 1:250,000 map scale and 0.804 when using Adindan at the same scale.

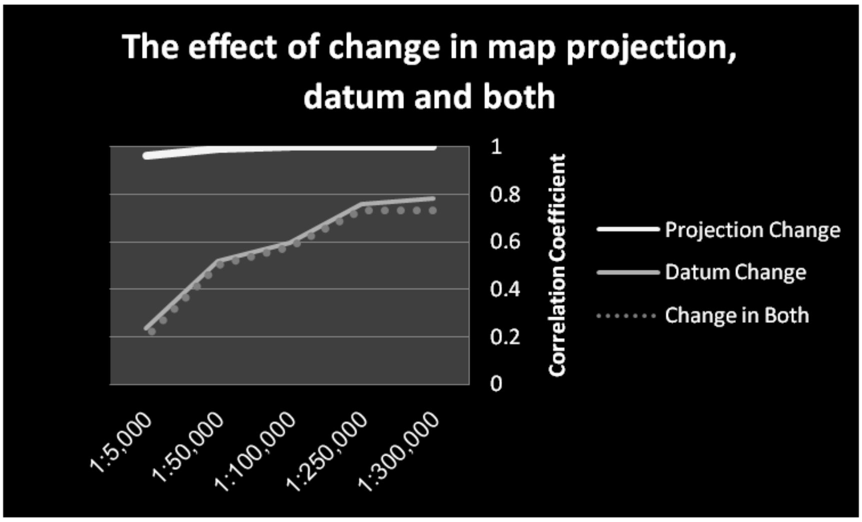

Figure (10): The effect of change of map datum in map matching.

According to this result, it is good to notice that distortion when transferring to WGS72 is less than that when we use Adindan. This is referred to the fact that the transformations parameters of WGS72 with WGS84 have less magnitude than that for Adindan. Also, the similarity between compared maps may reach 10% (r = 0.106) or less as for the projected map (WGS72, UTM) at scale 1:5,000 in the Gaza City case study. For comparing the same map at the same scale but for Rafah case study, similarity reaches 42% (r = 0.424). The reason for this variation in similarity between the two cases is that Gaza City map includes more detail than Rafah. Therefore, the amount of detail should be considered.

E. The effect of change in both map datum and projection

The effect on correlation by the combination of a change in map datum and projection is essential of being studied. Remarks can be excluded from the case study results and Figure (10). One of these is that the magnitude of correlation is quantified at various scales. Less correlation is as large as the scale is. Additional slight reduction in the similarity matching occurs besides that of the compared maps of datum changed. This increment is as a result of the new change happing in compared maps projection. As an example and for the Gaza Strip maps at a map scale of 1:50000, the correlation coefficient equals 0.983 for only a projection change, 0.519 is for only a datum change, but 0.502 is for the change in both datum and projection. Other numerical illustrations can be obtained by referring to Table (4).

6. CONCLUSION

The analysis shows that:

- The effect of change in map datum and/projection on spatial accuracy is less for small areas than for large ones. More distortion is for larger areas.
- The effect of change in map datum and/projection on spatial accuracy is more whenever the scale is large as being close to detail.
- The effect on spatial accuracy of change in map projection is less than that for change in map datum and the latter is less than that for change in both map datum and projection.

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