Generating a geotechnical map for the city of Nablus by comparing two functions of GIS software

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ABSTRACT:
Key words: Geotechnical map, IDW, Kriging, Thiessen polygon, spatial interpolation, ArcGIS, Soil type.

Geotechnical maps is a commonly used to support project and land use planning, It can provide engineers with information about soil type and its bearing capacity and therefore help to know the best location for specific building and the best type of foundation to be used in order to avoid problems that can be caused by soil such as swelling.
In this paper Geographic Information System (GIS) was employed to construct a knowledge base for geotechnical experts. The procedure based on employing the ArcGIS software and its extensions: Geo-statistical and Spatial Analyst in applying interpolation methods and representing results. Soil data for more than 100 boreholes logs distributed within city of Nablus were manipulated through ArcGIS software to test its capability for spatially modelling its types all over the city.

The interpolation procedures were implemented to display the soil type information for any point of the whole area. Kriging, Inverse Distance Weighting (IDW) and Thiessen polygon interpolation procedures were used to predict soil type's distribution. The qualitative description of the soil was turned into quantitative figures that could be interpolated by means of coding. The results of the study showed non realistic distribution for soil types at some places when using IDW and kriging methods, the minimum average error in predicated soil type was achieved when using the Thiessen polygon method.
It can be concluded that GIS techniques through ArcGIS and its extensions could be considered as a good base for developing an expert system for geotechnical investigation for soil types.

Introduction:
"The definition of soil varies depending on the person considering it. To a civil engineer planning a construction site, soil is whatever unconsolidated material happens to be found at the surface. To a miner, it is just some worthless material that must be removed. To a farmer, it is the medium that will nourish and supply water to the crops. So soil may have differing definitions, depending on the area of study. (R. Scharf)

The profile and texture of soil indicate the relative types of rocks and minerals that compose the soil, chief of which are sand, silt, and clay. Soil texture is an important indicator of the ability of soil to absorb and hold both water and plant nutrients. So it is important to develop an appropriate visual and quantitative representation of the soil type which named a Geotechnical maps. (Chris Lundber).

Geotechnical maps are widespread nowadays due to the existence of Geographical Information Systems (GIS) and Global Position Systems (GPS).
Geographic information systems (GIS) and modelling are becoming powerful tools in natural resource management. Spatially distributed estimates of environmental variables are increasingly required for use in GIS and models. (Jin Li and Andrew D. Heap, 2008)

The most obvious use of a geotechnical map is to indicate the types of the soil. This is clearly of great importance to civil engineers who, for example, have to advise on the excavation of road cuttings or to build up on this place or not; to geographers studying

the use of land, and ordering the data in geotechnical maps will save effort, time and provide easier using of data for engineering projects, especially in civil engineering field.

This paper describes two methods used in the production of a geotechnical map for the area of Nablus city using GIS program. The purpose is to use advance program (GIS) to make a geotechnical map for the soil type of Nablus city, based on the bearing capacity of these types, Several methods was used and the results was evaluated in order to select the methods that produce a map similar to the reality. Firstly, it talks about Nablus city and its location, data used in the study, methodologies that were used, and finally the results. The paper ends with a conclusion will and direction for future research.

Location:

Nablus district is located in the Central Highlands of the West Bank, some 63 km north of Jerusalem. Located in a strategic position between Mount Ebal and Mount Gerizim, it is the capital of the Nablus Governorate and a Palestinian commercial and cultural center. It is bounded by Asira alshemaliya from the north, Zwata and biet-iba from the west, Kufr qaleel from the south Wadi-elbadan, Roujeb ,salem and Deer-elhatab villages from the east.

Fig1:Nablus city-west bank

Data:

The required data was collected from geotechnical labs in the city by studying their reports, and some AUTOCAD maps for Nablus city which shows the distribution of soil in it. this map includes the surface soils and extend deep till the pressure from the foundations fades .
(Isam Jerdaneh, 2007)

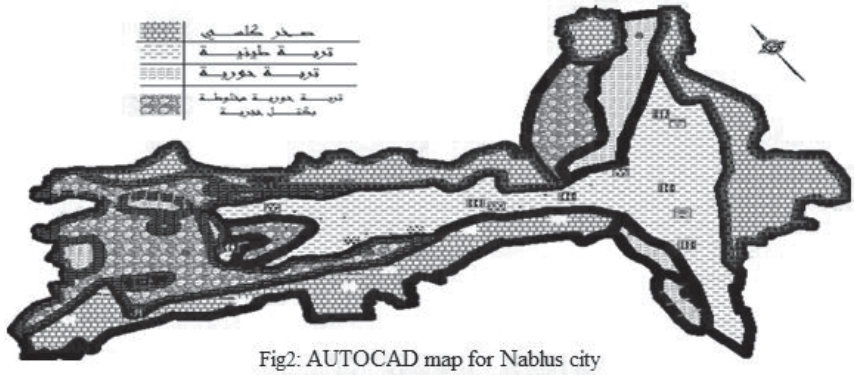
Fig2: AUTOCAD map for Nablus city

Methodology:

The geodatabase described in this work, was made in a way that all the information contained in the database could be easily imported to a Geographical Information System (GIS) and displayed spatially. The database contains information about bearing capacity of many points in different sites.

The data contained in the database, come from lab reports and then the database was linked to the GIS.

By using the GIS functions, we could predict the unknown values by different methods, however these methods are following Tobler second law (Tobler 1970) "Everything is related to everything else, but near things are more related than distant things."

Thiessen polygon:

This method assigns polygons whose boundaries define the area that is closest to each point relative to all other points. They are mathematically defined by the perpendicular bisectors of the lines between all points

In mathematics, it is a way of dividing space into a number of regions. A set of points (called seeds, sites, or generators) is specified beforehand and for each seed there will be a corresponding region consisting of all points closer to that seed than to any other. The regions are called Voronoi cells. It is dual to the Delaunay triangulation.

In the simplest and most familiar case, we are given a finite set of points {p1,...,pn} in the Euclidean plane. In this case each site pk is simply a point and its corresponding Voronoi cell (also called Voronoi region or Dirichlet cell) Rk consisting of every point whose distance to pk is less than or equal to its distance to any other site. Each such cell is obtained from the intersection of half-spaces, and hence it is a convex polygon.

- Inputs: A feature layer (Point, Polyline, Polygon)
- Outputs: New polygon feature class.

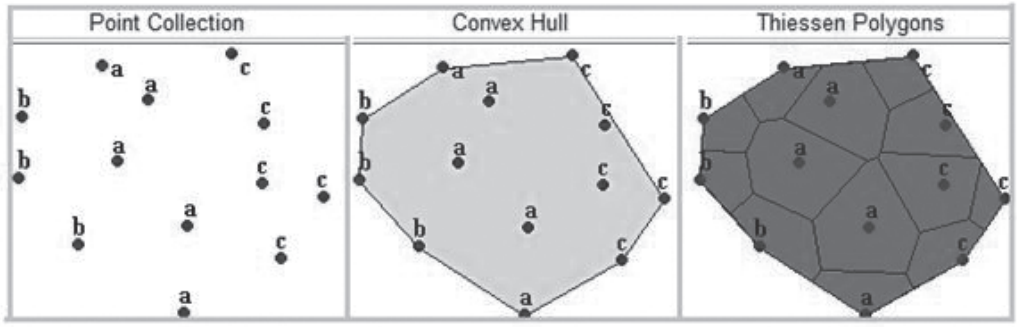

Fig3: Thiessen polygon

Thiessen polygons thus; Consider a set, S, of n labeled points in the plane, where:
S = {P1, P2 … Pn}
With each point, pi, in S we associate all locations, x, in the plane that are closer to Pi than to any other point, pj, in S(j≠ I). The result is to create a Thiessen polygon, Pi. More formally, if d(x, i) is the Euclidean distance from x to Pi then
Pi = {x |d(x, i) ≤ d(x, j); j " S, j ≠ i}
It is possible that x is equidistant from a pair of points, in which case it will lie on the boundary of Pi. In addition, x may be equidistant from three or more points so that it forms one of the vertices of Pi.
If Thiessen polygons are created for all points in S, then the resulting set of polygons
{P1, P2… Pn}, forms a unique, contiguous, space-exhaustive tessellation known as the Thiessen (Voronoi) diagram of S, V(S).
In other words, the area contained in a Thiessen polygon is likely to be more representative of the point on which the polygon is based than of any other point in the set. (Gordon, 2003)

After using this method to interpolate the soil map for the city of Nablus we got the result described in figure (4) below

2- Inverse distance weighting (IDW):

IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Therefore, IDW is the process of assigning values to unknown points by using values from usually scattered set of known points. This requires vectors of coordinates and variable values of known points (x,y,v) and calculated the variable values by means of Inverse Distance Weighting (IDW) multivariate interpolation for a vector or matrix (V int) unknown points described by coordinates (x,y)

$$\frac{\sum_{i=1}^{n} \frac{m_i}{d_i^2}}{\sum_{i-1}^{n} \frac{1}{d_i^2}}$$

Where di is the distance between x0 and xi, (distance from measurement I to the cell center is denoted by di), and n represents the number of sampled points used for the estimation.
(Esri, 19952013-)

For any unknown point, we take some form of weighted average of the values at surrounding points to predict the value at the point where the value is unknown, In other words, we create a continuous surface from a set of points , Figure (5)

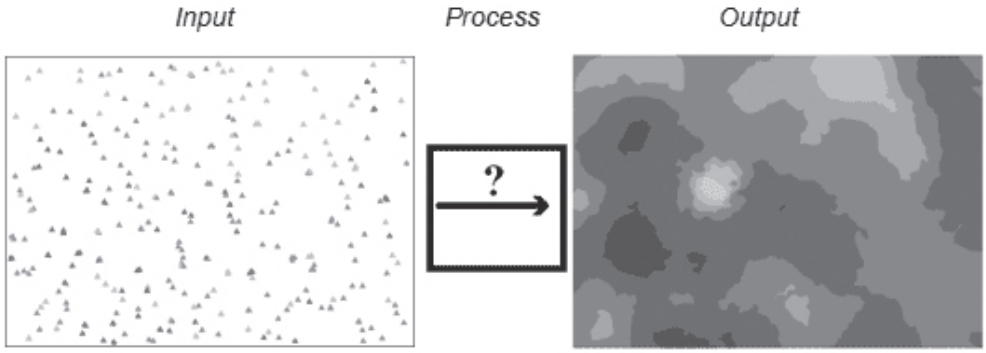

Fig5: Interpolation by Inverse distance weighting

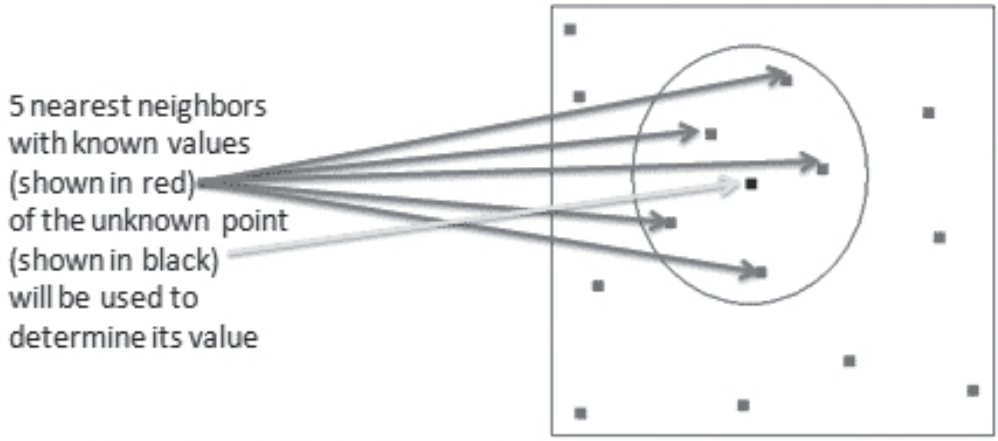

Fig6: Interpolation by Inverse distance weighting process

Figure (7) describe the resulted soil map for Nablus using this method.
The result shown below in fig (7):

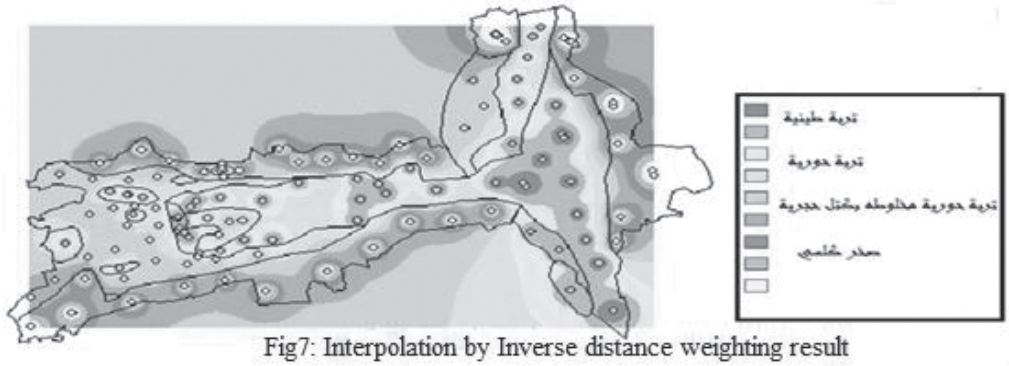

Fig7: Interpolation by Inverse distance weighting result

Results and conclusion:

This work presents some functions that are used in GIS program to generate surfaces. The resulted surface represents a geotechnical map that can be of great help for the planning of the cities.

The functions adopted in this paper are used to determine which one of them is more suitable and recommended to be used in similar geological conditions; here are some reasons that why the Thiessen polygon is more suitable than IDW?

* Firstly, field is a geographic phenomenon which can be discrete or continuous.

- A discrete object has known and definable boundaries: it is easy to define precisely where the object begins and where it ends.
- A continuous surface represents phenomena in which each location on the surface is a measure of the concentration level or its

relationship from a fixed point in space or from an emitting source, another type of continuous surface includes phenomena that progressively vary as they move across a surface from a source.

When the field which we want to construct assumed to be discrete, it is preferable to assume that any unmeasured location has the value of closest measured point by constructing polygon around the measured point so all points inside this polygon will be assigned the value of this measured point; this means generating discrete field representation from point data using Thiessen polygon technique.

But, using interpolation is more common when the data which we are dealing with is considered to be continuous (gradual changing in data), this mean generating continuous field representation from point data.

Soil type is a typical example of discrete field.

* Secondly; if the resulted maps that we have from the two methods are compared with the original map we find that Thiessen polygon gives more accurate map which is closer to the original one, they are shown below. and as it seems from the results of map that IDW needs more measurement points to give better result but may be for Thiessen polygon it was almost enough.

As a result the Thiessen polygon method is preferred.

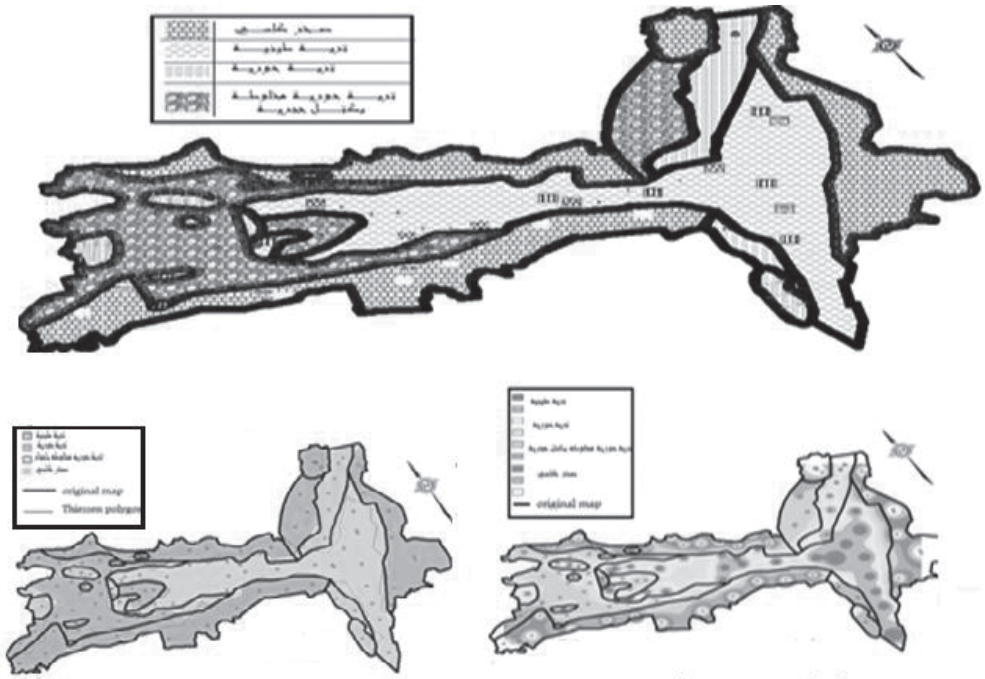

Fig8: why Thiessen polygon method is preferred than IDW method

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