Assessment of Soil Suitability for Agriculture Using GIS Spatial Analyst Model Technique

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Abstract

The purpose of this model application is to asses the suitability for cultivation of a 50,000 faddans in Sinai Peninsula by using GIS spatial analyst modeling technique which is considered a unique powerful tool for spatial analysis and decision making. This specific analysis model was accomplished through investigating three main points. The first focused on the slope of land topography, water resources, and the existing roads. The second dealt with the reconnaissance soil survey this comprised of the morphological description of the investigated soil profiles and the chemical and physical properties of the soils. Then the third one was the development of a spatial analyst model to asses the soil potentiality for cultivation. Typically, this model contains several processes, which are chained together in such a way that output from one process becomes input at next level. The major output of the model is a soil potentiality map. The output cultivation land suitability map shows the relative suitability of land in a planning area for cultivation-type development, thus helping the decision makers to plan the area for cultivation with all necessary instructions and managements.

Keywords: GIS, Land Suitability for Cultivation, Spatial Analyst Model, Sinai, Egypt

Introduction

The agriculture expansion in the desert areas is one of the main objects of the national plan in Egypt to meet the food requirement for the tremendous increase in population. Sinai Peninsula represents a major area for potential expansion of agricultural land in Egypt; particularly that fresh water from the River Nile will be transported through El-Salam canal to the area. The Water Distribution and Irrigation System Research Institute of the National Water Research Center (1991) had carried out a reconnaissance soil survey on 50,000 feddans south east Suez Canal in Sinai Peninsula to establish soil conditions and produce maps that describes the suitability of soils for agriculture. These maps were developed manually not digitally, which is a less effective mean in presenting the output results as geo-referenced soil maps , and in being not retrieved , visualized ,or stored.

GIS utility is a powerful technique in analyzing huge soil data in a digital format of high accuracy. This huge soil database generated in GIS environment could be used in spatial analyst model. This approach could yield soil potentiality maps by using the weighted overly analysis tool inside the model. This Spatial model, besides being an easy fast access to necessary information and thematic maps, it will also provide the framework for all future soil studies in a specific area as it could be continually updated and improved as new information is received from future intensive soil studies, thus maximizing its use and helping decision makers to have an easy access to the information and determining what locations are most/least suitable for development , hence making the right decision in a proper time .

The objective of the present work is to establish a new spatial model using model builder under GIS environment to process soil data of the survey study of the Water Distribution and Irrigation System Research Institute (1991) for interpreting soil data, developing soil maps, and then automatically creating a soil suitability map for cultivation using a chain group of GIS tools. Hence advantages in use of GIS spatial model in handling soil data are demonstrated in this paper.

Study area

The study area (fig.1) is a part of that narrow strip in Sinai Peninsula which extends along the Suez Canal and a part of Suez Gulf. Its length is about 59 kilometers, its width lies between 2.5 and 7.0 kilometers. The total area surveyed is approximately 50,000 feddans. In general the area lies between latitude 29° 52 and 30° 34 north and longitude 32° 38 and 32° 64 east.

The distribution of different soil groups and soil association according to terminology outlined by FAO 1979 is as follows (fig1):

Soil groups

1. Sandy soils(S)
2. Sandy stony soils (T)
3. Sandy dune soils (D)
4. Rocky plateau(R)

Soil associations

1. Deep sandy soils (S_0)
2. Deep sandy soils with gypsum (S_1)
3. Sandy soils with clay hardpan (S_2)
4. Sandy soils with gypsum hardpan (S_3)
5. Sandy stony soils with stones on the surface (T_f)
6. Sandy stony soils with stones in the lower layer (T_l)
7. Sandy stony soils with stones throughout the profile(T_p)
8. Like T_f but with gypsum (T_{f1})
9. Like T_l but with gypsum (T_{l1})
10. Like T_p but with gypsum (T_{p1})

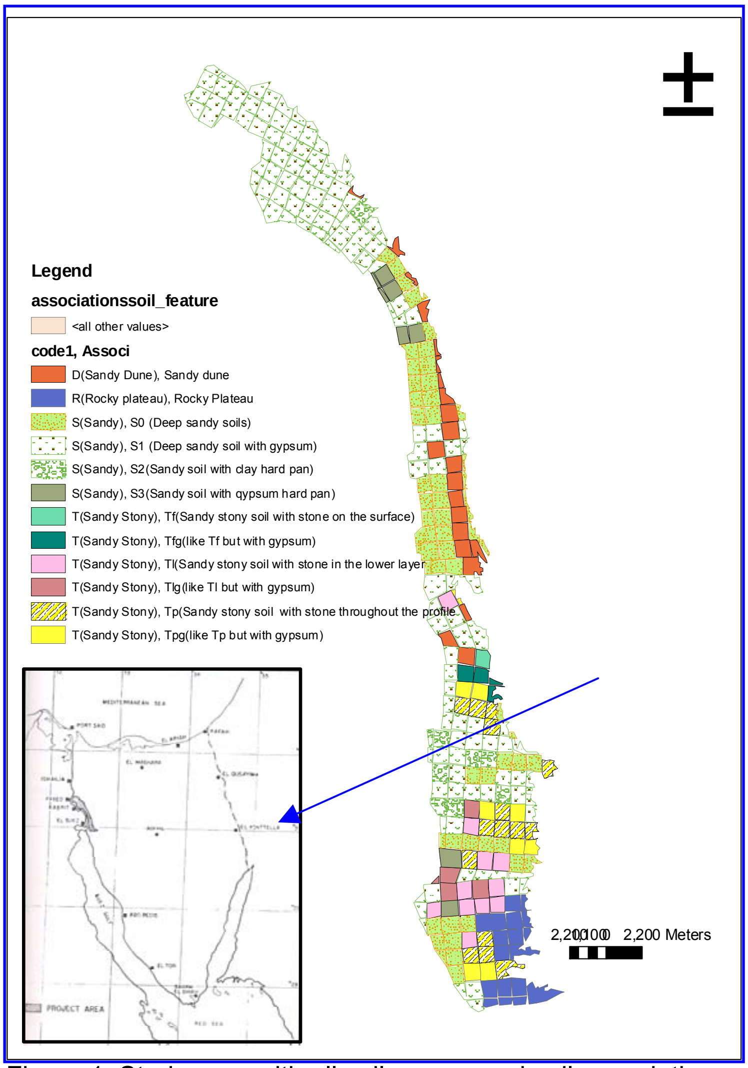

Figure 1: Study area with all soil groups and soil associations

Model development methodology

A model builder tool within the ArcGIS Spatial Analyst extension was used to create the model in order to best document the data and processes used and results obtained. Model builder works by pulling tools into a workflow diagram, which can be used to run the model in its entirety or to run discrete segments (ESRI,2004). To perform this land suitability for cultivation model the following steps were undertaken:

1. Defining two criteria for the analysis. The first related to site selection i.e. land topographic, proximity from water resource and roads intersections , and the second to soil suitability for cultivation defined as soil groups ,salinity classes and slope variations.

2. Listing and collecting data needed for model analysis as water resource availability, topographic hardcopy map, soil morphological characteristics and attributed data that describes soil profile test results .

3. Utilizing computer based analytical environment for data capturing, storage, manipulation, and analysis under *GIS* environment.

4. Listing and defining comprehensive spatial, topographic, and surface analysis (hill shade, slope …) of the investigated area based on collected soil data, topographic maps and attributed data that describe soil characteristic and salinity factor.

5. Using model builder tool under spatial analyst GIS environment for cultivation suitability analysis using several needed tools inside map builder. The data and processes are brought into the model via the workflow diagram, which links data to processes to achieve an output. Outputs may be used as inputs to other processes.

Putting the model in running mode needs the following:

1. Data preparation of the study area

Preparing Digital maps (using scanning and geometrical correction processing) of the study area with scale 1:250000 which is quite adequate for this reconnaissance study.

- Digitizing vector layers for the features needed for the analysis i.e. spot height, contours, roads, lake, Sinai canal (fig 2)…etc.

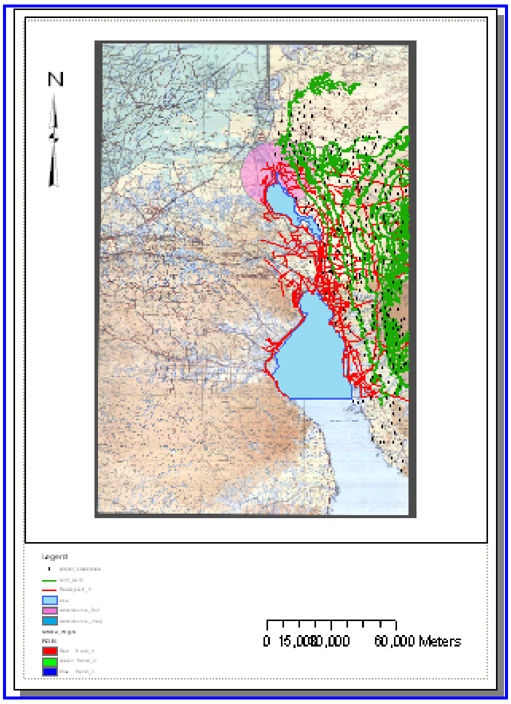

Figure 2: The digitized layers

- Joining Description data for salinity and soil profile codes with the soil morphological digital map that describes soil groups and associations using GIS join tool (fig 3).

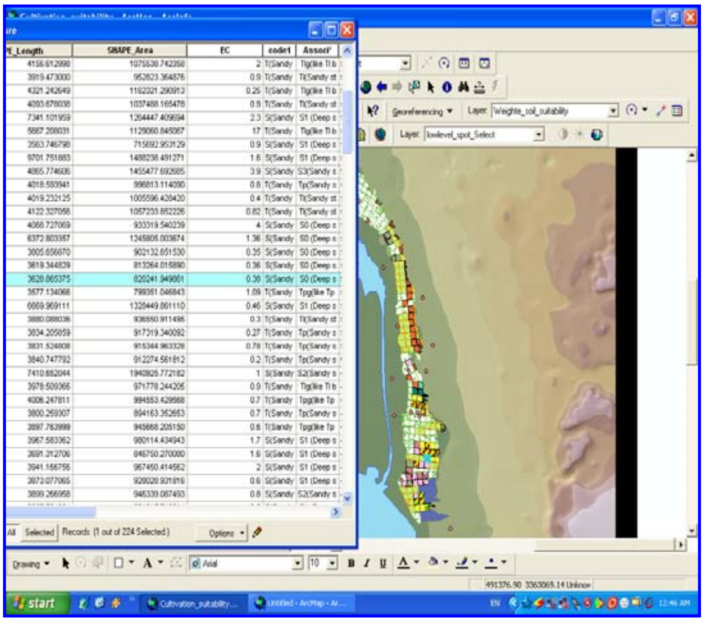

Figure 3: The soil morphological data as an attributed table

- Preparing logical flow diagram for the operations needed for this analysis to produce the potential cultivation map automatically with final symbology for cultivation types.

2. Identifying of GIS operations performed

Some of these applied operations are vector to raster conversion, buffer, reclassification, surface analysis (topo to- raster interpolation) □□, creation of hill shade, slope surface, and contour map (fig 4) , which are created from the topo to-raster surface, spatial analyst –weight overlay.

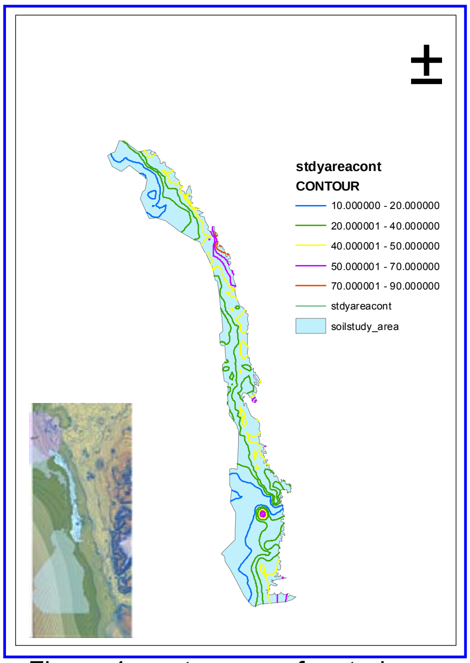

Figure 4: contour map for study area

Operations functions:

- Cut and Fill as a topographic analysis for land leveling.
- Feature to raster – Converts vector data (for example polygons describe the area of sample soil) to raster format (fig 5).

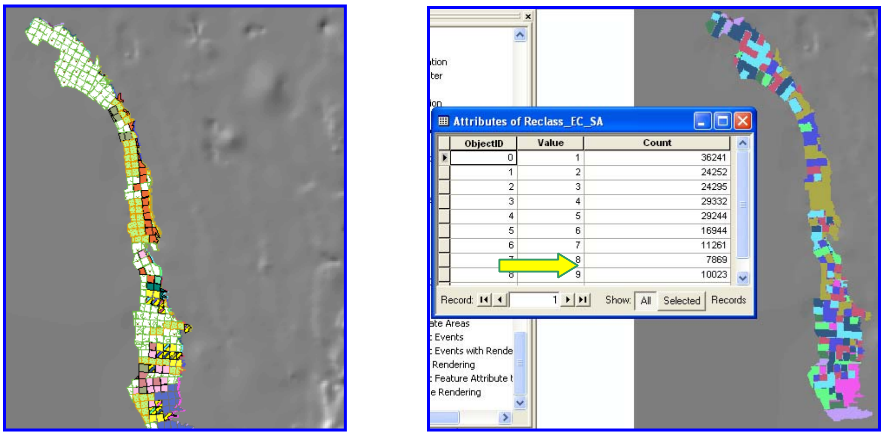

Figure 5: Feature to Raster conversion tool

- Reclassification – Group the values in a grid theme into new classes and assigns them new values that interpret the levels of suitability (fig 6).

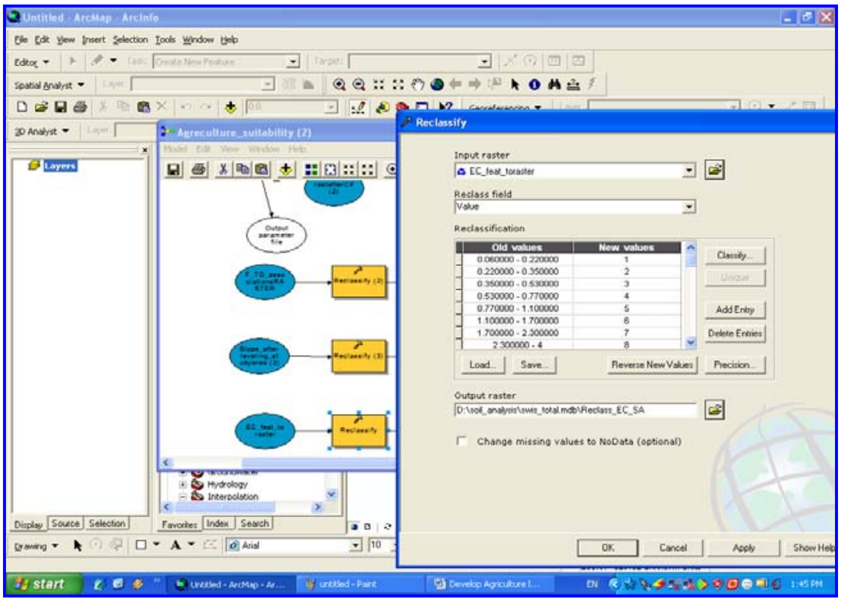

Figure 6: Reclassification tool

Three layers have been chosen for weighted overlay processing tool, soil morphological map that shows groups and associations, soil salinity map that shows salinity classes, as the excess of salts is one of the main unsuitability criteria eliminating more extend of cultivation areas (Richards, 1954), and also a slope condition map .All being in raster format and each layer receives an influence weight ,and develops the final potential cultivation grid. The overlay is based on percent of 100. In this specific analysis model, morphological map classes receives 80 percent of weight and salinity map classes receives15 percent, while the slope classes receives 5 percent (fig 7).

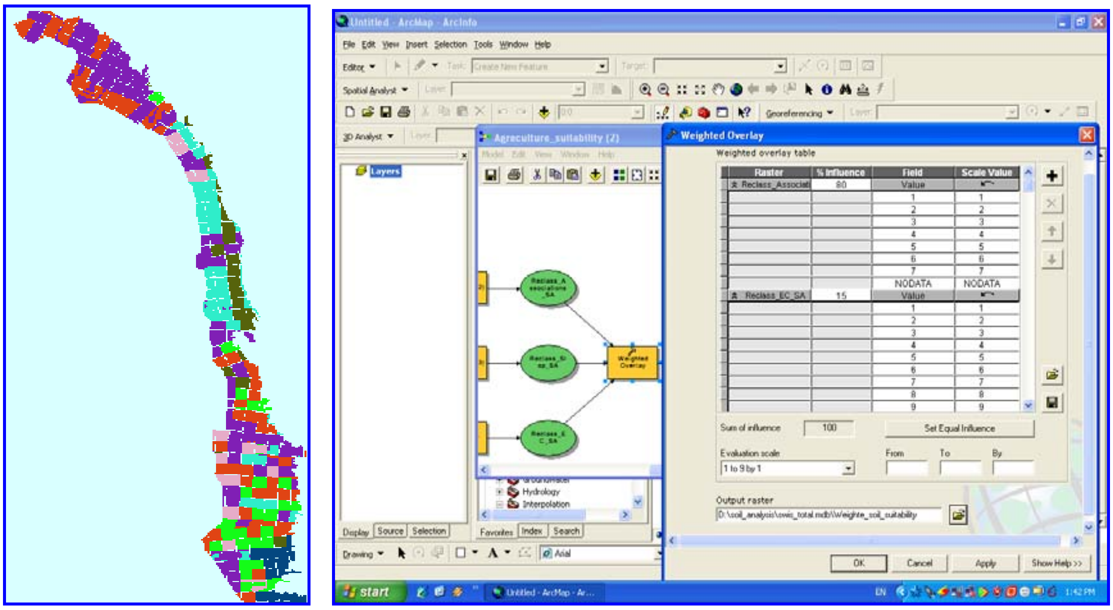

Figure 7: Snapshot of the weighted overlay tool, output overlay map in raster format.

The weighted overlay tool of spatial analyst creates the final output for potential soil map suitable for cultivation .Some important tools are used to finalize the output potential map like, clean-boundary ,and to-vector conversion and cultivation subtypes

3. Running every processing tool inside the model builder individually to check the performance and the data output.

4. Integrating all the tools and the data necessary for operations together in continuous manner and running the entire model as one operation (fig 8), taking into consideration that the model should be interactive, enabling decision-makers to modify the weighting factors used in the analysis and can be re-run to evaluate the new results.

Model run time varied between the two sub models based on their complexity. The entire cultivating suitability model can be run in 5–10 minutes depending on the complexity of the functions and the speed of the processor.

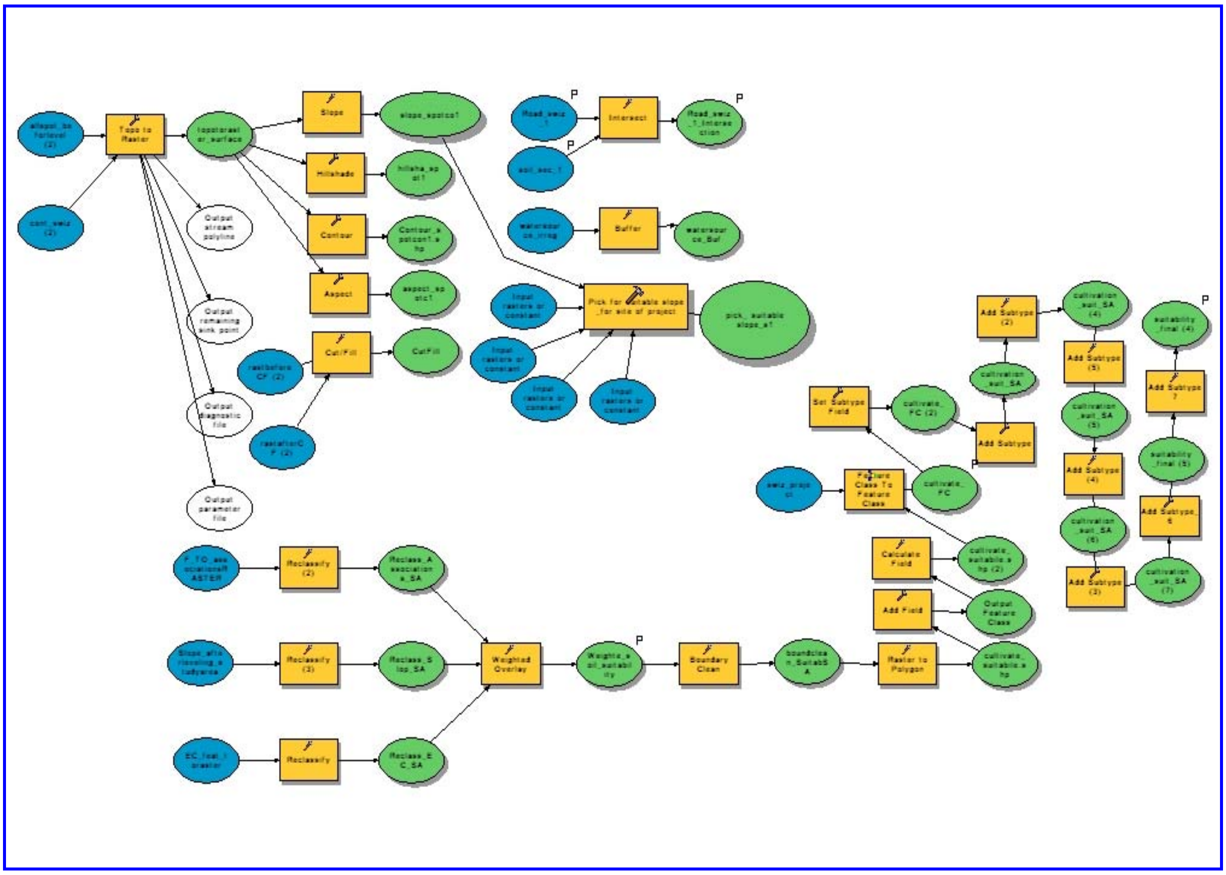

Figure 8: Model builder workflow diagram

Results and Discussion

Using GIS soil groups and associations are ranked according to the slope condition and salinity risk, then by analysis thematic maps were prepared. The areas prone to soil salinity, slope condition and suitability for cultivation are shown in fig 9.The soils have been classified into seven levels for irrigated agriculture. The results of suitability classification are demonstrated in figure 10 as an output map which shows that areas with green color are the most suitable for development with varying management limitations, i.e. slight moderate and strong limitations, imposed by soil morphological characteristics, soil salinity and slope condition. On the other hand areas with red and brown color are the least suitable, being respectively sand dunes and rocky plateau. Suitability levels and the suggested cultivation types for each level are clarified in table 1

From the above illustrations, it is clear that the use of GIS spatial analyst model in soil data handling makes decision making process easier for planners to manage the area for cultivation with all necessary instructions and precise soil management solutions.

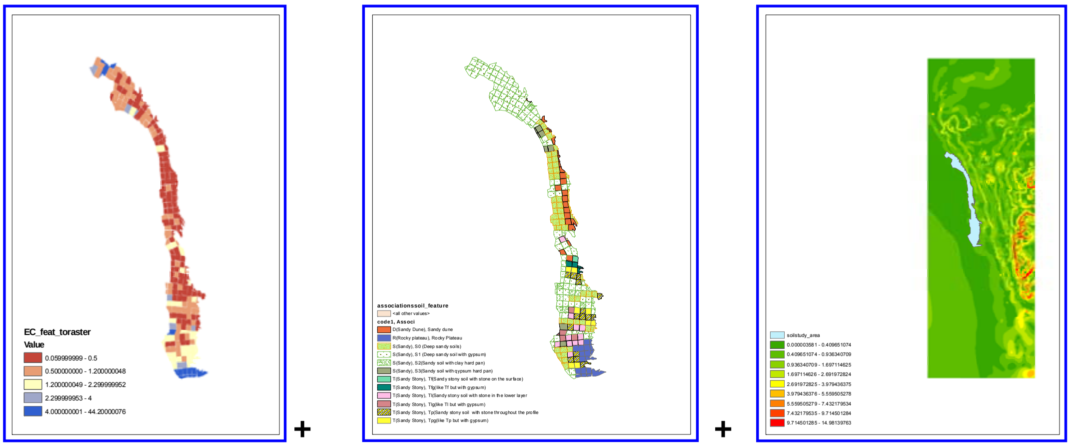

Figure 9: Salinity map +Soil group map + Slope map

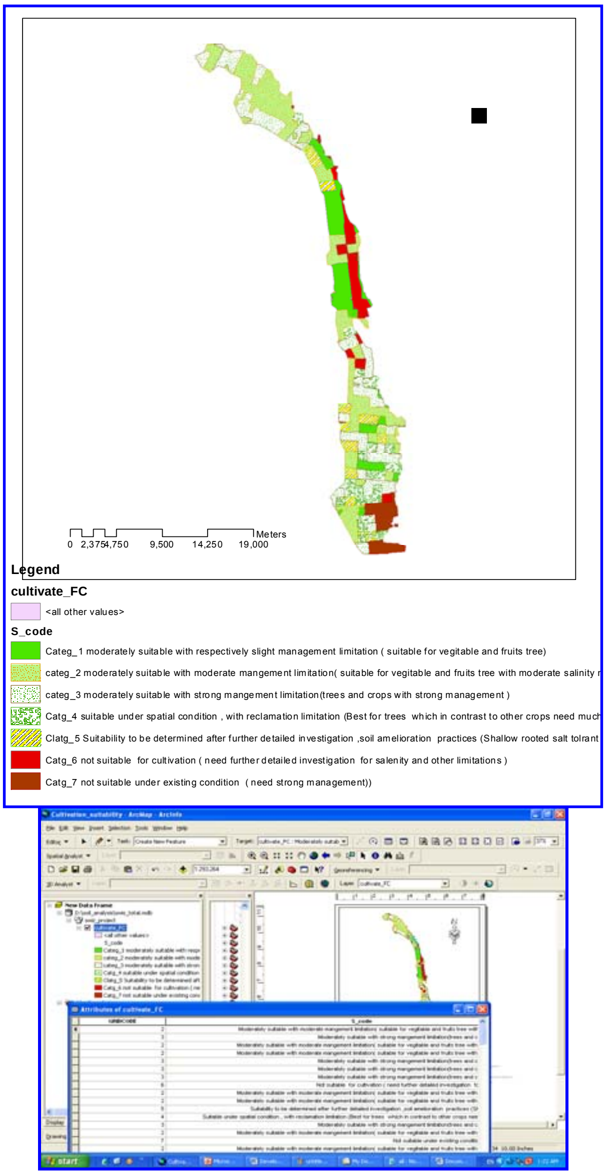

Figure 10: Output soil suitability for Cultivation map with attributed data

Table 1: Output suitability levels and suggestion for cultivation type

GRIDCODE (Classes)	Suitability levels
1	Moderately suitable with respectively slight management limitation (suitable for vegetable and fruits tree)
2	Moderately suitable with moderate management limitation(suitable for vegetable and fruits tree with moderate salinity management)
3	Moderately suitable with strong management limitation(trees and crops with strong management)
4	Suitable under spatial condition , with reclamation limitation (Best for trees which in contrast to other crops need much management practices)
5	Suitability to be determined after further detailed investigation ,soil amelioration practices (Shallow rooted salt tolerant crops)
6	Not suitable for cultivation (need further detailed investigation for salinity and other limitations(
7	Not suitable under existing condition (need strong management)

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