REMOTE SENSING AND GIS APPLICATION IN AGRO-ECOLOGICAL ZONING IN YEMEN MOUNTAINS

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ABSTRACT : Sustainable agricultural development requires a systematic effort towards the planning of land use activities in the most appropriate way, apart from several other institutional and policy programme initiatives. Agro-ecological zoning (AEZ) is one of the most important approaches for agricultural developmental planning because survival and failure of particular land use or farming system in a given region heavily relies on careful assessment of agro-climatic resources. This approach is used to categorize agro-climatically uniform geographical areas for agricultural developmental planning and other interventions. Modern tools such as satellite remote sensing and Geographical Information System (GIS) have been providing newer dimensions to effectively monitor and manage land resources in an integrated manner for agro-ecological characterization. The application of AEZ is limited by lack of geospatial data, particularly in mountainous areas. This paper tries to demonstrate incorporation of new tools to extend applicability of AEZ in mountainous areas like Yemen Mountains, Yemen.

1. INTRODUCTION

This paper focus for study the Agro-Ecological Zone characteristics of the Yemen Mountains region , which is a vast plateau bounded by mountainous terrain. Yemen Mountain Region is the important area in Yemen due to centralize the population and Agriculture activity, the land use in this region is centralizing also. Agro-ecological zoning (AEZ) is one of the most important bases for sustainable agricultural developmental planning of regional or local areas; it is applicable in micro or local level planning mainly for rainfed agriculture. A framework of agro-ecological zoning describing concepts, methods and procedures was conceptualized for the first time by FAO (1976). The definition of the Agro-Ecological Zone is a land resource mapping unit, having a unique combination of land form, soil and climatic characteristics and/or land cover having a specific range of potentials and constraints for land use (FAO, 1996). Yemen Mountains is mainly composed of mixed intensive agriculture. The AEZ that exists were those created by Agricultural Research and Extension Authority (AREA) with cooperate with Food and Agricultural Organization (FAO) in 1997 and utilized more of soil samples, crop growing periods and thermal regimes (AREA, 1997). The result for all Yemen to five main agro-ecological zones, The Coastal Plain, Western Mountains, Highland Plain, Eastern Mountains and Eastern Desert Plain (AREA, 1997).Yemen Mountains had only two zones: Western Mountains and Highland Plain zones. These two zones do not give a true characteristic of the whole region hence prompting a more precise method with many zone characterizations that utilizes land use, elevation structures, soil types, climate and land inventory datasets in a GIS platform. This therefore became the motivation for this study. Satellite remote sensing and GIS have been providing newer dimensions to effectively monitor and manage natural resources. Remote sensing provides digital copy data base information on natural resources. The nature of analysis, which involves the combination of layers of spatial information to define zones, lends itself to application of a GIS. The major requirements of computerized GIS for an activity like agro-ecological zoning and zonal resource information of mountain areas are topographic maps, land resource maps and contour maps. The use of remote sensing in relation in Yemen Mountains to determining parameters of the vegetation indices, surface temperature, Evapotranspiration and Crop water Requirements (CWR) are important. Almhab . & Alhakamy, 2008a, and Almhab, 2009a, studies the ageo-climate change and vegetation index change in the Arabia Peninsula , using low and medium resolution remote sensing and recommended that more research needs to be done to determine whether this relationship still holds between different species and over different geographic regions. Almhab &Busu, 2008a,b,c,d, and Almhab , 2009b and 2011, has developed M-SEBAL model for estimate of the Evapotranspiration and crop water requirements in the arid mountain regions. Almhab and Tol, 2010, have calibration the estimation of the precipitation from the TRMM satellite image with many of rainfall gage stations in Yemen. The parameters used in the definition above focus attention on the climatic and land resources requirements of crop and on the management systems under which the crops are grown. The Objective of this Research was to derive method for representing Agroclimatic variability, the Agroclimatic index under Yemen Mountains region , and assessment of Agroecological zoning for biodiversity conservation, rangeland rehabilitation, a biotic stress identification, and development planning, and, To Improve climate monitoring. An output of AEZ studies includes maps showing agro-ecological zones and land suitability, quantitative estimates on potential crop yields and production. These maps, containing physiographic, geographic, and bio-climatic information form primary inputs. Various outputs are generated in both tabular and map forms.

2. Materials and method

2.1. Study area

Yemen is located in the south western part of Asia and in the south of Arabian peninsula, between latitude 12 ^{o} and 20 ^{o} North and longitude 41 ^{o} and 54^{o} East. The country is bordered by Saudi Arabia in the north, Oman in the east, the Arabian Sea and the Gulf of Aden in the south, and the Red Sea in the west as shown in figure (1). Recent demarcation of Agroecological zones in Yemen is not comprehensive, but the country could be divided into three major zones (figure 1) derived from the five Physical divisions [Bamatraf&Ghaleb, 1999] these are: The Coastal Region, The Mountainous Region, Eastern plateau. Yemen has predominantly semi-arid to arid climate. Rainy seasons occur during the spring and summer . The climate of Yemen is strongly influenced by the mountainous nature of the country [AREA, 1997]. Rainfall rises from less than 50mm along the Red Sea and Gulf of Aden coasts to a maximum of 500-800mm in the western highlands and decreases steadily to below 50mm inland. Yemen Mountains is located in the western of the country along from the south to north.

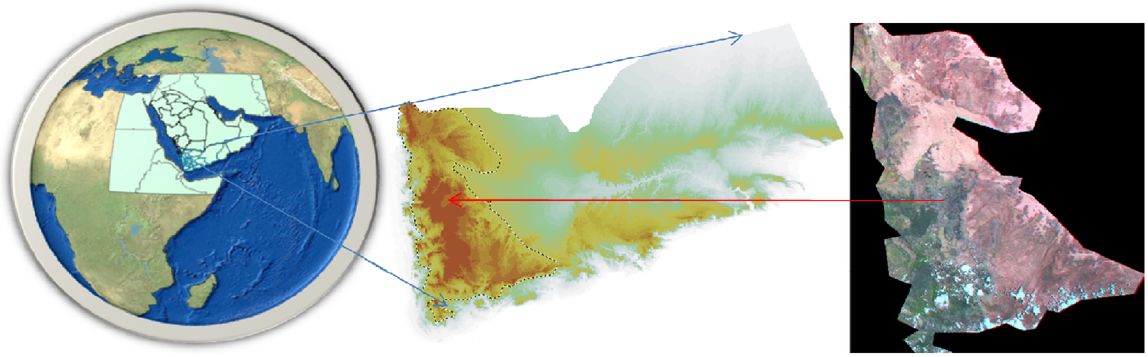


Figure (1) located of area of study Yemen Mountains.

2.2. Dataset

Two Satellites images MODIS with 1 km resolution, required during year 2012 cropping season period, were evaluated for Land Surface parameters in Yemen. Both images had favorable weather conditions without or little clouds in the study area. Data from the field measurement area were available to assist the calculation of the Land Surface parameters in the locations of the study area (Lat: 15.3 ^{o} N, long: 43.15 ^{o} E). In additional to satellite image data, field observations have also been collected. This included sampling from the field measurement, test and gathering the meteorological ground conditions at the study area.

2.3 Research Methodology

In this study, Agro-ecological zones database assessment model will be build up in ilwis SMCE following the steps below:

2.3.1 Create the structure of Agro-ecological zone assessment model

All indicators will be integrated into a GIS database to get the final map. The model of this assessment of Agro-ecological zones database will be built in ilwis SMCE (spatial multi criteria evaluation) (Figure 1). Each of these indicators is a layer of the final map.The primary databases were created by digitizing the land systems and land capability maps.

2.3.2 Create each indicator map

Each indicator map will be created and will be reclassified according to the relation of the elements in each map to the AEZ. The different score will be assigned to each elements.

2.3.3 Weight each indicator map

In ilwis SMCE, different weight will be assigned to each indicator according to their contribution to the Agro-ecological zone, using pairwise comparison weighting method.

2.3.4. Integrate all indicators in GIS

Combine all indicator maps with different weight to create the final map. The final map is an “Index Overlay with Multi-class Maps”, it means that the map classes occurring on each input map are assigned different scores, as well as the maps themselves receiving different weights.

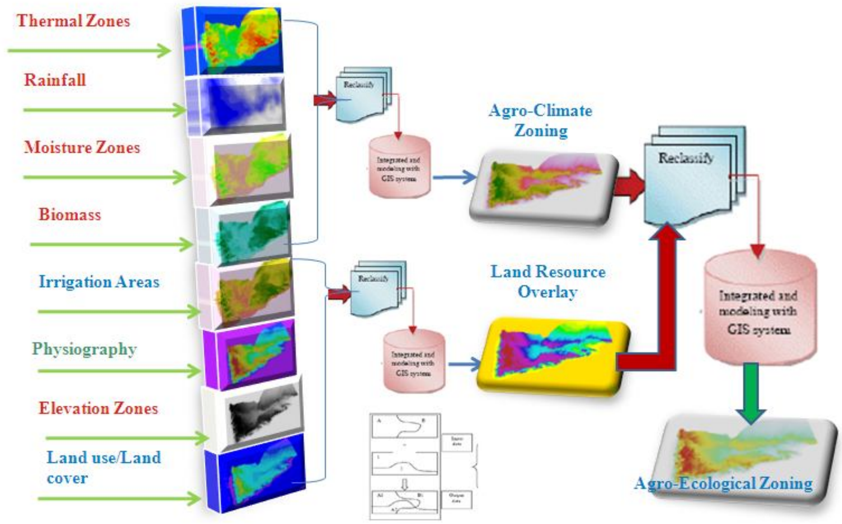


Figure2.The Agro-ecological zones database assessment model in ilwis SMCE.

2.3.5 Assessment of Agro-ecological zone in Yemen Mountains.

In the Yemen Mountains area, it is difficult to get all the data related to the Agro-ecological zone. All available data will be used. So far, temperature , rainfall, evapotranspiration, soil moisture, biomass, soil , land cover (vegetation) , Land use, elevation, slop …and topography will creating from remote sensing images and chosen as the indicators.

2.3.5.1 Surface Temperature indicator

Created Surface Temperature using MODES image in Erdas

Reclassify the Temperature map;

Assign different weight for each class according to the relation between the Temperature areas and AEZ;

2.3.5.1 Soil indicator

1. Created soil map, using MODES image in Erdas Imagen.
2. Reclassify the soil map;
3. Assign different weight for each class according to the relation between the soil type and AEZ;

2.3.5.3 DEM and Slope indicator

1. Create DEM and slop map;
2. Classify the slope map;
3. Assign different weight for each class according to the relation between the slope angle and AEZ;

2.3.5.4 Landcover (vegetation) indicator

1. Created normalized difference vegetation index (NDVI), using MODIS image in Erdas;
2. Apply density slicing to NDVI;
3. Reclassify the NDVI and check with the field records;
4. Assign different weight for each class according to the relation between the land cover and AEZ;

2.3.5.5 Land use indicator

1. Create Land use map based on MODIS images interpretation and check with known points and field records or use Landuse map of (AREA, 1997) and edit it with new data;
2. Reclassify the Landuse map;
3. Assign different weight for each class according to the relation between the landuse and AEZ;

2.3.5.6 Soil moisture indicator

1. Create soil moisture map using MODIS images and M-SEBAL model, interpretation and check with known points and field records or use soil map of (AREA, 1997) and edit it with new data,
2. Reclassify the soil moisture map
3. Assign different weight for each class according to the relation between the soil moisture and AEZ;

2.3.5.7 Historical Climate Data:

1. Created climate data such as temperature, vegetation index, evapotransperation, crop water requirement and soil moisture are produce using MODIS images and M-SEBAL model. interpretation and check with known points and field records or use AREA, data.
2. The rainfall was downloaded from TRMM website.

3. Data from the AREA having collecting data for Yemen Mountains since 1986 to 2008. Part of this data was also used in this study. Table 1 below show the means of both temperature and precipitation (1986 to 2008) to validate historical data and it tallied well with 'M-SEBAL' model data (Almhab, 2012).
4. Reclassify the soil moisture map
5. Assign different weight for each class according to the relation between the soil moisture and AEZ;

2.3.5.8. Irrigation areas indicator

1. Create soil Irrigation areas map using MODIS images interpretation and check with known points and field records and edit it with new data,
2. Reclassify the soil moisture map
3. Assign different weight for each class according to the relation between the soil moisture and AEZ;

2.3.5.9 Climatic resources database.

1. The climatic resources database was generated by integrating temperature layer , prsipetation layer, soil moisture layer, and irrigation areas layer.

2.3.5.10 Agro climatic zoning

The agr0-climatic zoning was derived by combining the climate, land resources inventory and irrigated areas layer

2.3.5.11 Land resources database.

The land resources database for the study area was created by integrating the soil resources layer and climatic resources layer.

2.3.5.12 gro-ecological zoning

Agro-ecological zones database was created by integrating the agro-climate layer and land resources layer.

2.4. Software : Erdas Imagine 8.5 and Illwis used in this study.

Table 1. Annual Average Temperatures and Precipitation from Weather Stations around Yemen Mountains from (1986 to 2008) Almhab, 2012.

P	NR	Sun hour	U km/sec	RH %	T c	Elev	North	East	Governorate	Station name	n
140	20.9	8.4	388	35	17	2200	15	44	Sana'a	**Aleraah**	1
-	19.9	7.9	119	29	19	1990	17	43	Sada'a	**Aldomaid**	2
-	17.7	6.2	151	61	30	70	15	43	Alhodaidah	**Alzuhrah**	3
620	20.8	8.3	142	55	25	1400	13	44	Taiz	**Osaiferah**	4
-	20.7	8.2	50	64	28	65	13	45	Abyan	**Alfush**	5
403	20.9	8.4	111	55	24	1100	15	43	Hajjah	Hajjah	6
310	21.1	8.4	75	41	22	1150	13	44	Althali	Althali	7
243	21.2	8.6	183	41	16	2300	14	44	Dhamar	**Rasabh**	8
-	20.7	8.2	96	68	28	130	13	44	Lahj	**Lahj**	9
-	21.8	8.9	140	75	26	20	13	45	Abyan	**Alkood**	10

3. PRELIMINARY RESULT

On visual inspection, both the Surface Temperature map (Figure3) created from MODIS remote sensing images bands 31, 32, the result between 273 to 320 Kelvin, it show different value estimates in farms areas compared to non-farms areas and the Rainfall map (Figure 4) created from TRMM remote sensing images yearly combined, the result between 83 to 1150 mm/year, it increasing in the Ibb governorate southern of the study areas more than1000mm/year, then decrease in the other areas in the region and country.

Digital Elevation System (DEM) images (Figure 5) showing the elevation in the study areas from 1170 to 3487 meter above sea level and Slope indicator (Figure 6) create from DEM image using ERDAS imagine, it show result between 0 to 80%, show (represented by lighter grey tones), it contain 4 groups mean depend on slope aspect there are; western slope, eastern slope, southern slope and highland plains.

Normalize Difference Vegetation Index (NDVI) images (Figure 7) created from MODIS images bands red and infrared bands, it showresult between 0 to 1, and the Actual Evapotranspiration (ETa) images (Figure 8) created from MODIS satellite images and M-SEBAL model it show result value between132 to 2044 mm/year. It show higher estimates in farms areas compared to non-farms areas.

The Soil moisture indicator images (Figure 9) divide to four classes: arid, semiarid, dray sub humid and humidity, and the Potential Evapotranspiration (PET) images (Figure 10) created from MODIS satellite images and M-SEBAL model it show result value between 500 to 4061 mm/year.

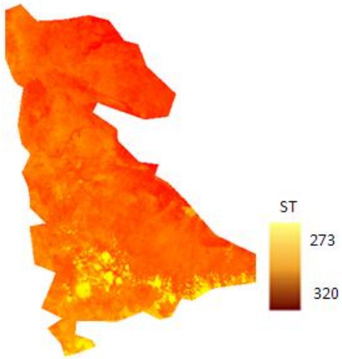


Figure3.The surface Temperature Kelvin.

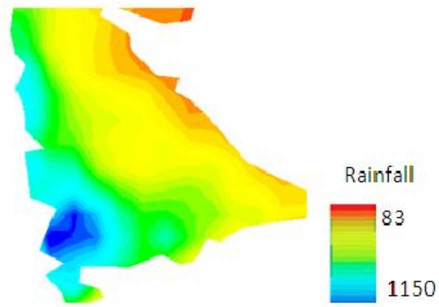


Figure4.The rainfall map mm/year.

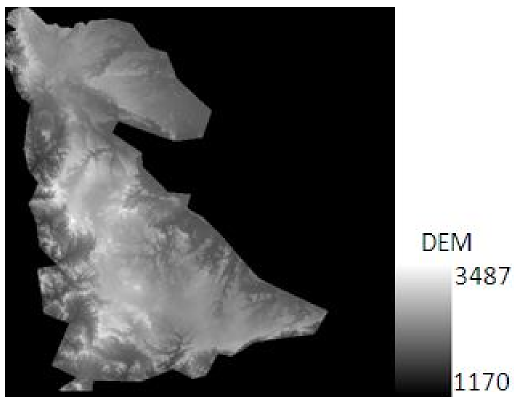


Figure5.The digital elevation model (DEM)

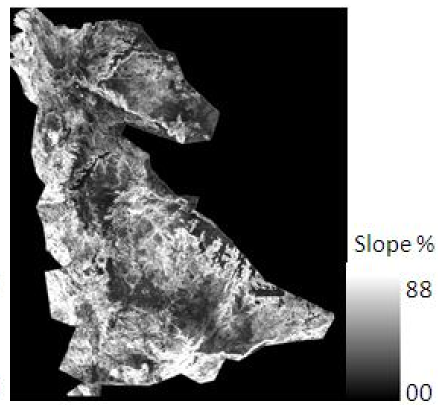


Figure6.The Slope map %

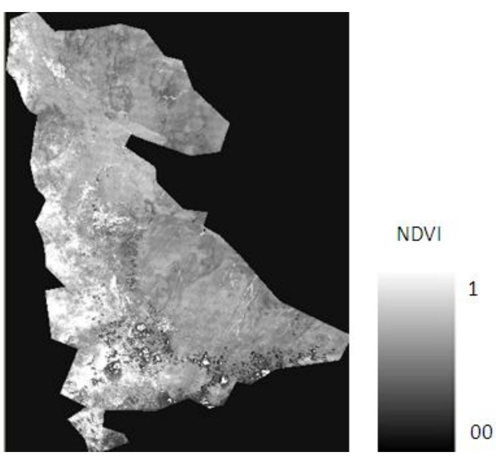
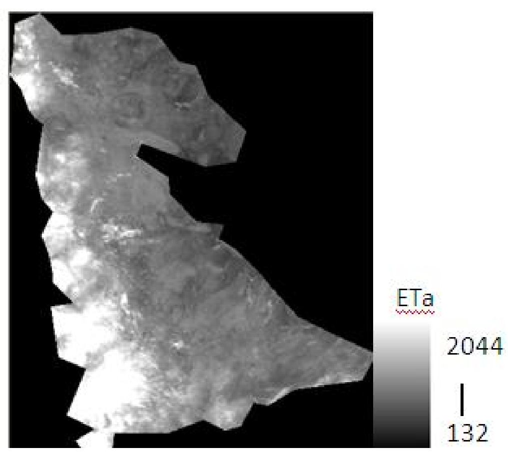


Figure7.The NDVI for the study Area



. Figure8. Actual Evpotranspiration (ETa). mm/year

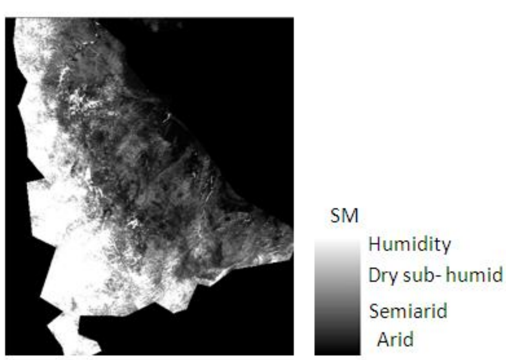


Figure9. The soil moisture for the study

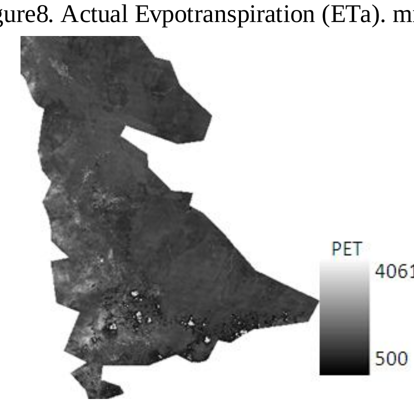


Figure10.The potential Evpotranspiration (PET). mm/year

The Soil indicator (Figure 11) it divided to five main classes there are: Aridisols, Inceptisols, Entisols, Mollisols and Rock out crops. Table 2 shows the areas. However, visual inspection is not enough to determine the accuracies of the satellite based estimates and need more research doing in future. But in general The Yemen Highlands have large stretches of plains between the mountains which constitute extensive loamy, silty and fine silty soils on level surfaces, one third of which bear organic matter within the surface layer. Associated with these soils is a minor component of clay soils, which also have a dark layer rich in humus. These constitute very productive agricultural lands. On the lower slopes of the highlands silt loams and silty clay loams prevail, while the flat basins comprise silty and loamy soils. The Eastern Slopes region comprises mainly rock outcrops, with some shallow soils confined to pockets. Deep loamy soils are only encountered within local depressions and wadis.

The Land use (vegetation) indicator (Figure12) and it divided to 6 classes depending on the agriclture land use the are : Uncroped, Rainfed, Irrigation area, Single Season Crops, Double Season Crops and Perennial Crops table 3. Historical Climate Data, additional to the date create from satellite images compared with climate database collected from 9 meteorological station summarize in Table 1.

The Agro climatic zoning map was development (Figure13) it contains five classes they are: Hyber arid , Arid , Semi arid , Sub humid and humid table 4.

Finally the result of combination all maps above to create the Agro-ecological zoning (Figure 14) as output of this study in the Yemen mountains areas, using the modeling in GIS environment figure 2. The result show twenty two AE sub zones this zones integrated to 5 mains AEZ are identified in the study areas, it present in figure 14. AEZ 3 and AEZ 5 are the most potential zones for intensive cropping with possibility of two or more crops per year, due to counting the main basins between the mountains, and centerline the agriculture and human activities.

Table 2. Type of the Soils created from satellite images In Yemem Mountans

Type of the Soils	Areas - Ha
Aridisols	372981.25
Inceptisols	1164343.75
Entisols	2053937.5
Mollisols	2527450
Rock out crops	1636575

Table3: Agricultural Land Use in the Yemen Mountains area. The total area agrees with the area of the MODIS image depicted.

Land use class	**Area (ha)**
Uncroped	10116462.5
Rainfed	788512.5
Irrigation area	2934137.5
Single Season Crops	3098875
Double Season Crops	1674318.75
Perennial Crops	425943.75

Table 4 the Agr-Climate Zones in Yemen Mountains

zone	Areas/ ha
Hyber arid	1177181.25
Arid	1636575
Semi arid	2527450
Sub humid	2053937.5
humid	1164343.75

Table 5 the Agr-Ecological Zones In Yemen Mountains

zone	Areas/ Hectare
AEZ1	10105781.25
AEZ2	467587.5
AEZ3	2566256.25
AEZ4	4021181.25
AEZ5	1877443.75

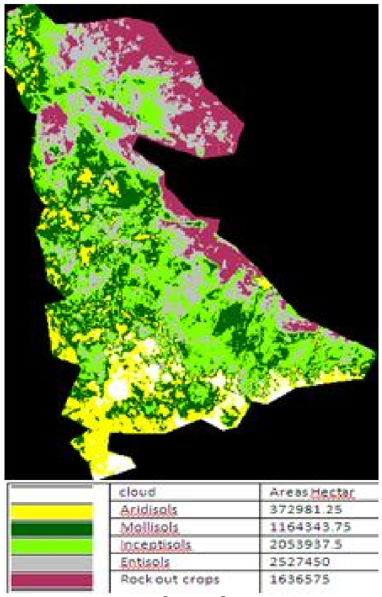


Figure11.TheSoil type map

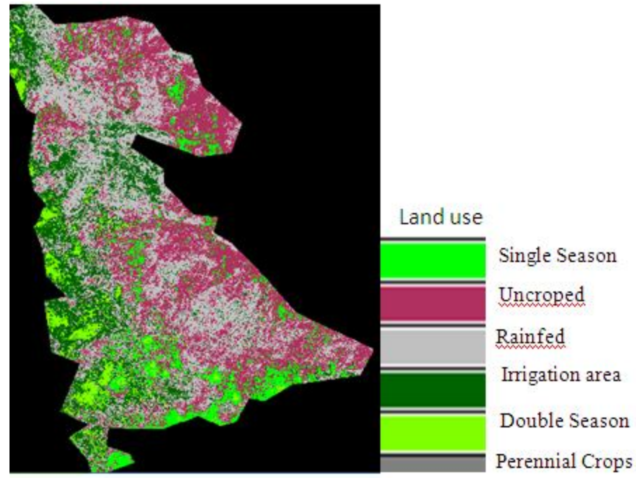


Figure12.The land cover proposal map.

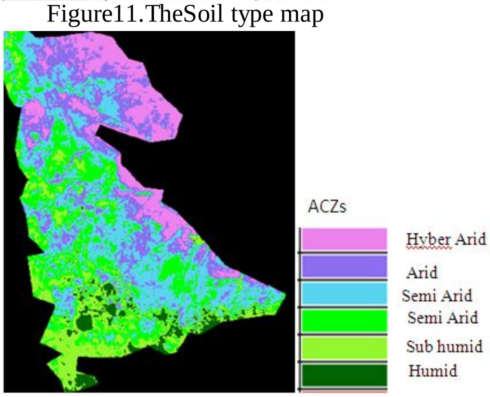


Figure13.The Agr-Climate Zones map

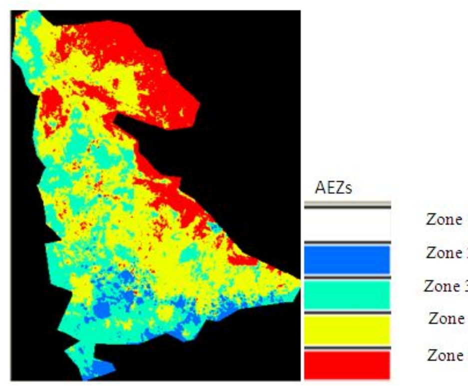


Figure14.Agro-Ecological Zones map

4.CONCLUSIONS

The presented methodology could serve as an effective method for Agro-Ecological Zones development in mountains environments. Thus, the classical methods such as those basis on physiography, climate, soils and agricultural regions works and interpretation of aerial photographs are better to be enhanced by a prior suitability analysis. It presents that Remote Sensing data and Geographical Information System techniques are useful tools for produce Agro-Ecological Zones maps in mountains areas, almost of the parameters in this papers was developing from remote sensing and M-SEBAL model can produce many of parameters other than ET with good accuracy result in different areas, especially in arid mountains areas. The study has explored and discovered the usefulness of AEZ as a forceful method to produce better map which generates better result in the overall decision making process. Based on AEZ map developed, suitable land use suggested.

More research needs to be done in the future to involve many complicated factors including weights, parameters, judgments and consistency of matrices where the assistance of computer software is needed in driving results future improvement. Also more research needs to be doing in determine soil maps , texture, depth,…. to determine the relationship between the parameters still holds and between. More research needs to be done different species, over different geographic regions with high resolution images.

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