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E7.3 10988

NASA-CR-133767

Title of Investigation	Application of ERTS-1 Imagery to Land Use, Forest Density and Soil Investigations.
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Date	August 25, 1973
Type of report and period covered	December 1972 - July 1973
Name and address of national sponsoring agency	Greek Atomic Energy Commission Agia Paraskevi, Attiki GREECE

(E73-10988) APPLICATION OF ERTS-1 IMAGERY TO LAND USE, FOREST DENSITY AND SOIL INVESTIGATIONS Progress Report, Dec. 1972 - Jul. 1973 (Nuclear Research Center) 37 p HC ~~$4.00~~ CSCL 02F G3/13

N73-33244

Unclas 00988

37pp.

1. SR No. EO 375 2. Type of Report II	3. Recipient's Catalog No.
4. Title. Application of ERTS-1 imagery to land use, forest density and soil investigations	5. Report Date August 25, 1973
	6. Period Covered December 1972- July 1973
7. Principal Investigator Nicholas J. Yassoglou	8. No. of Pages 33
9. Name and Address of Principal Investigator's Athens Faculty of Agriculture Botanicos, Athens, Greece. or N.R.C. Dimocritos Ag. Paraskevi, Attiki, Greece	10. Principal Investiga. Rept. No 2
	11. GSFC Technical Monitor G. Ensor
12. Sponsoring Agency Name and Address Greek Atomic Energy Agency Agia Paraskevi, Attiki Greece	13. Key Words (Selected by Principal Investigator) Remote sensing, agriculture, forestry, soils, site.
14. Supplementary Notes	

15. Abstract

Photographic and digital imagery obtained by ERTS-1 was analyzed and assigned to land features related to agricultural and forest resources.
Land use and forest site evaluation maps were prepared by comparing remote sensing and ground truth data. Relationships found in this investigation between spectral signatures recorded by ERTS-1 and land features can be used for the assessment and development of agricultural and forest resources.
The results are applicable to areas with ecological and geological conditions similar to those of Greece.

CONTENTS

PREFACE

The objectives of this investigation were to determine whether remote sensing data obtained by satellites could be used in recognizing, evaluating and mapping land features and resources.

The emphasis of this investigation was placed on the study of land features related to agriculture and forestry such as : present land use, ecological sites, forest density, soil properties and soil chartography.

ERTS - 1 was successfully launched on July 29, 1973 and recorded remote sensing information over Greece on August 2, 1972.

Photographic and digital imagery was made available by NASA in December 1972.

Two frames covering sites of Eastern Greece were analyzed both in Greece and at LARS of Purdue University in the U.S.A.

Gray scale classes on the black and white photographic imagery were assigned to land use patterns. Ecological sites were recognized on the false color composit imagery.

Digital data were analyzed by computer using the LARSYSAA program. Spectral classes were recognized analyzed statistically and were assigned to detailed land use features and semidetailed soil units.

The results of this investigation show that remote sensing data, obtained through satellites, can be used for the recognition and mapping of land features.

The relationships between the spectral signatures and ground truth, which were found in this investigation, are applicable to the local ecological and geographic conditions of Greece. They can also be extended to other countries with similar land and climatic conditions.

The conclusions of this investigation are particulary important to developing countries where surveys and information on land resources are limited. In these cases a quick inexpensive and relatively reliable evaluation of agricultural and forest resources can be achieved both on a permanent and on a temporal basis.

THE STUDY PLAN

Ground truth information were collected prior to the lanching of ERTS - 1. Data affected by temporal variations were collected on the date the satellite obtained information over Greece.

Black and white photographic imagery was studied first and gray scale classes were related to land use features and to forest density.

False color composit photographs were use next to further separate land use features, evaluate agricultural and forest sites and classify soils.

Digital imagery was proccessed at LARS using the LARSYSAA computer program to determine detailed land use classes, map crop distributions and to recognize salinity and drainage condition of the soil in selected small areas.

Land feature maps prepared from photographic and digital imagery were checked in the field and their accuracy was tested. Thus improved relationships between ground truth and spectral information were achieved.

RESULTS AND DISCUSSION

1. Studies on Photographic Imagery

The aims of the study of photographic imagery received from ERTS - 1 were the following:

1.1. The recognition of land use patterns.

1.2 The recognition of class of plant vigor(site evaluation classes)

1.3 The recognition of some soil features.

1.1. Land Use Patterns.

The recognition of the land use patterns was based on the study of the gray scale classes and texture of the RBV and MSS black and white and of the false color composit images.

Vegetation was best separated from bare land on the RBV channel 2 and MSS channel 6 imagery.

The photographs were studied with the use of a magnifying viewer and a stereoscope. Eight gray scale classes were visually recognized and were related to land use feature shown in table 1.

Table 1 Gray Scale Classes and corresponding land use features.

Gray Scale Class increasing brightness	Land Use Features
0	Water
1	Irrigated summer crops Dense fir and Austrian pine forest
2	Marginally irrigated orchards, dense pine forests and dense hardwood forests.
3	Thin pine, thin hardwood forest and shrubs.
4	Shrubs, scattered pines and olive trees, bare soil and rocks.
5	Olive groves, vineyards, some scattered pine trees and shrubs.
6	Non irrigated winter crops-bare soil and soil with harvested wheat. Rocks with thin shrubs.
7	Rocks - Residential areas

Detailed ground truth data were used for the assignment of land features to the respective gray scale classes.

Table 1 shows that each gray scale class corresponds to more than one land use features, which in some cases are quite different. From the practical point of view it is necessary that these groups of land use features be separated. This separation was achieved by making use of existing geographical and geomorphological information and by the use of the false color composit picture as follows:

Water corresponds to the darkest gray scale class on the black and white photographic imagery.

The next darkest class 1 covers well irrigated annual and perennial agricultural crops as well as dense fir and austrian pine forest stands.

The agricultural crops can be separated from the forest by their geographical distribution. Well irrigated crops are grown on flat bottom land, while fir and austrian pine are grown on high mountainous terrain. These two land forms can be easily recognized and separated on the 1:1000.000 photographic imagery by their characteristic textures as it is discribed in the soils section of this report.

On the false color composits the irrigated agricultural crops are bright red, while the fir-austrian pine forests are dark red. Thus they can easily be separated from each other.

In gray scale class 2, dense Halepo pine and hardwood forests could not be separated on the black and white picture from marginally irrigated orchards. It is known, however, that Halepo pine grows mainly along the coastal areas of southern Greece and at an elevation not exceeding the 800 meters. On the contrary hardwood species form forest stands in the central part of the country and at elevations usually exceeding the 500 meters. Thus in most cases, with few exceptions, halepo pine can be separated from the deciduous forests. In false color composit the deciduous forest shows a brighter red color than the pine forest. This subject will be eleborated on in the study of sites.

Orchards are found in Greece mainly on recent alluvial or quaternary deposits, which are easily delineated on the 1:1000.000 scale space photograph. Small localized areas covered with orchards are also found on some mountain slopes along with pine and deciduous forest. These can not be separated from each other on the 1:1000.000 photograph.

In gray scale class 3 the separation of thin pine forests from thin deciduous forest and shrubs presents similar problems, which can be also solved by considering the spatial distribution of the species.

This class, due to the irregural mixing of thin forest stands with shrubs, bare soil and some dense stands, has a characteristic texture consisting of small areas of different brightness.

Gray scale class 4 corresponds to degrated slopping land, which due to severe grazing and lumbering, has lost a great part of its vegetational cover. Consequently intensive erosion has exposed the bedrock on a large portion of surface of the land. Due to the high reflectivity of the bare soil and exposed bedrock, the pattern of this class is brighter than the previous class. The texture, however, is the same in both classes.

Olive groves and vineyards in Greece are in most cases non-irrigated crops. Bare soil represents about 50% of the total area and therefore contributes significantly to the reflectivity of the land surface. Due to the dry climate and the lack of irrigation, the plants suffer during the summer months from moisture stress and thus they absorb less visible light. Consequently this class is only slightly darker than the bare soil. Geomorphologically these crops grow mostly in Southern Greece on quaternary deposits and on the slopes of tertiary formations.

The separation of this class from the following class of winter crops on the black and white photographs is difficult.

On the false color composit, class 5 shows a yellowish-orange tinge and thus can be separated from the yellowish white color of class 6. The separation of class 5 from class 4 is relatively easy because of the difference in the brightness of the surface.

Due to the fragmentation of the cultivated areas and the brightening effect of the large portion of the bare soil, the separation of vineyards from the olive groves is not feasible on the 1:1000,000 space photographs.

Gray scale class 6 is brighter than the previous classes, because during the period of August, when the data were obtained by ERTS - 1, the respective land surfaces consisted either of bare soil or of harvested winter crops, principally wheat and barley.

Class 6 is not easily recognized from class 7 in the gray scale. Class 7, however, is mainly located on mountainous terrain while class 6 is located on the quaternary and tertiary deposits of lower lands.

Class 7 corresponds mainly to bare soil and rock outrops located on the eroded mountainous land and to residential areas, which in Greece usually have sparse vegetation.

The vegetation of the lands of class 7 consists of sparse small shrubs of predominanly xerophytic species. Thus the reflection pattern is determined by the soil and bedrock surface.

Class 7 is the brightest of all the recognized by naked eye gray scale classes. Its separation, however, from class 6 is difficult on the black and white photograph. On the false color composit photograph, however, it has a distinct bluish white color peculiar to this class only.

1.2. Ecological Site Evaluation

The subhumid and the semi-arid climatic zones cover the greatest part of Greece's productive lands. Therefore the water supplying power of the soil during the dry months is a critical and in many cases the limiting factor for the growth of the plants.

The conditions which affect the water supplying power of the soil in the agricultural lands are the natural soil drainage and the applied irrigation water.

In the forest and rande lands these conditions are the local climate, the geology, the soil depth and texture, the slope of the land and its geographical orientation (aspect).

The moisture stress in the soil affects the chlorophyl content and the turgidity of the plant leaves. Consequently the reflectivity of the vegetation in the infrared region can be used as a measure of the effectiveness of irrigation in the agricultural lands and the site quality of the forest and range lands.

The false color composit space photographs show a range of red colors corresponding to vegetation. A close inspection of the areas of various degrees of brightness of the red color on the photograph indicated the possibility of assigning them to respective site classes.

Ground truth data collected through extensive field observations confirmed the above hypothesis.

It was found on high elevations, where the climate is humid to sub-humid, that the dominant factor which influences the water supplying power of the soil is its depth. In these areas the red bright color corresponds to vegetation grown of deep soil, while less bright red color is found on sites with shallower soils.

The deep residual soils are normally found in Greece on mica schist and on interbeded sand-stone silt stone - shale. Thus, the colors on the photograph can be correlated with the geological substrutum. Exceptions to this observation are few, confined to areas of small slope, where deep soils form also on other parent materials.

On the lower lands and hills, where deep soils are developed on quaternary and tertiary deposits, the dominant site factor is the distribution of the rainfall throughout the year and not the soil depth. A side evaluation map was made on the basis of the above observations. The following site classes have been recognized and mapped in central Greece:

Site 1 corresponds to well irrigated agricultural lands. The bright red color in the plain of Kopais and in the alluvial fan of Lamia are characteristic of the well irrigated summer crops, in this site.

Site 2 includes agricultural lands, where irrigation is localized and water is applied in limited quantities.

The forest and range lands were classified into three site classes on the basis of the visually estimated brightness of the red color.

Site class 3 shown in the map of Central Greece has bright red color and it includes lands with relatively deep soil, which has adequate water storage capacity. These lands are located in the humid zones of the mountains. A typical example of these lands are the eastern slopes of Pilion Mountain. The forest species have a high rate of growth, the reforestation is easy and returns of investments are considered satisfactory.

Site class 4 shows on the photograph a less bright red color than class 3. The lands of this class are located: a) on humid mountainous regions with soils of moderate depths and b) on subhumid lowlands and hills with soils of adequate depth. In both cases the water supply power of the soil during the summer is relatively low. Thus the productivity of the lands of site 3 is moderate.

Site class 5 shows a reddish brown color on the photograph. The lands of this class are characterized by a summer drought and/or shallow soil. The growth rate of the forest species is low, reforestation success is limited and pastures are dry during the summer and fall months. Investments for the development of these lands will produce limited or doubtfull returns.

Site 6 is on exceptionally dark the photograph and it is under study. Preliminary observations show that the color may be correlated with damaged pine trees, which are under intensive resin exctraction treatments.

The above site classification could be considered the most valuable achievement of this investigation so far. Site classifications made by conventional methods would require scil mapping vegetational mapping and detailed climatic data. All these projects need a long time, extensive scientific and technical personnel and substantial funds. ERTS - 1 data on the contrary can provide a basis for a quick reliable and inexpensive ecological site evaluation.

The site classification map which was made on the basis of false color composit 1:1000,000 scale space photograph can be used for the planning of the forest and range development of Greece on a more solid and scientific basis that it has been done so far. The results of this investigation could possible be extended to other countries with similar climatic conditions.

1.3. Soil Features

The following classes of soil groups have been recognized on the black and white and on the color infrared space photographs:

1.3.1. Severely eroded mountain soils on mountain lands.

These lands have lost most of their soil and bedrock is exposed on the largest part of the surface. Due to the absence of soil,deep enough to support vegetation, these lands are bright on the black and white photograph and bluish white on the false color composite. Since their soil is considered practically unproductive, the knowledge, of its extend and distribution in the country is necessary for the planning of resource development. The space photographs provide a quick, inexpensive and relatively accurate estimate of these soils. Class 10 in the land use map represents this group of soils.

1.3.2. Saline Soils

Most of the saline soils of Greece are associated with the imperfectly and poorly drained soils of the coastal plains. Due to salt limitations the vegetation is poor and in the summer months is either dry or under stress. The color of the soil is dark except in small spots, where, due to the precipitation of fine salt crystallites, is almost white.

Since the saline soils are localized in relatively small areas, where they are mixed with non saline soils, the 1:1000,000 scale space photograph is not very convenient for their indentification in the coastal plains of Greece.

Black and white photographs produced by the computer at LARS from digital MSS data at X 16 magnification can be used for the indentification of the coastal saline soils of Greece.

The separation was made by comparing the computer produced photographs of the green channel with those of the infrared channel.

A test area was selected in the Skala coastal plain south of Sparta in Peloponnese, where detailed ground truth information was collected.

In August irrigated crops, wet land and saline soils are shown dark on the green channel photographs. Thus, they cannot be separated.

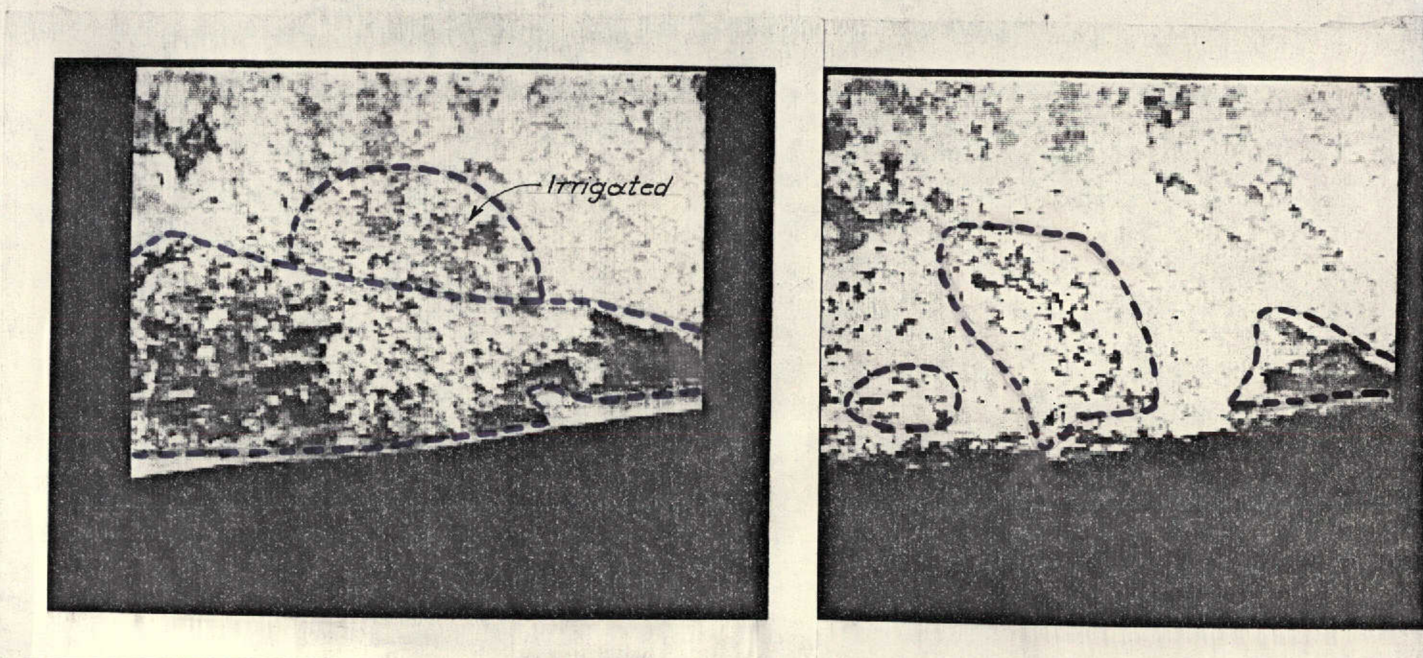
On the photograph of the infrared channel, however, irrigated crops and vegetation on wet land are highly reflective and cover light areas of the photograph. On the contrary, the saline soils are dark both in the green and in the infrared band. Due to moisture stress the reflectivity of the vegetation is also low and contribute to the darkness of salt affected areas.

Saline soil can be separated from the non saline bare soils of the area by comparing the above photographs. Bare non saline soil is less reflective than the saline soil in the infrared band. Thus, they are shown as light spots in the green channel and dark in infrared channel, while as it was indicated above the saline soil appears dark in both channels.

1.3.3. Wet Soils

Poorly drained soils are generally darker than well drained soils. Their differences in the reflectivity were not great enough to allow a direct soil drainage classification in the 1;1000,000 scale space photographs. Temporal differences may be a useful tool, but at present such data are lacking.

The recognition of poorly drained soils and wet lands in a semiarid and subhumic country, such as Greece, can be based on the reflectance of the vegetation.



a b

Fig. 1. Computer proccessed digital MSS imagery of Scala, Plain, Sparta, Greece.
a. Green band showing wet and saline soils.
b. Infraved band showing the saline soils and bare surfaces.

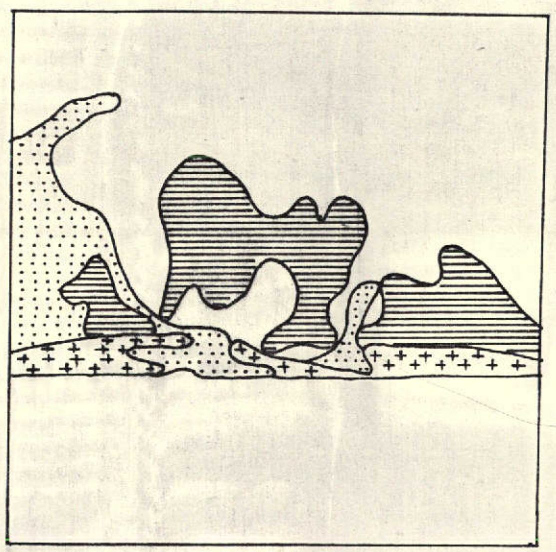


Fig. 2. Soil map of Scala, Plain, Sparta, Greece.
Saline soils.
Poorly drained soils.
Sand dunes

As it was discussed in the land use and the site evaluation sections of this report, a high water supply capability of the soil causes a sharp decrease in the reflectivity of the vegetation in the visible bands and an increase in the infrared bands.

The reflectivity of the plant leaves is known to decrease in all bands with increasing water content. The increase in the brightness of the red color in the false color composit photographs which was observed on sites with adequate supply of soil water can be explained by the denser vegetational cover in these areas.

In areas where soil water is a limiting factor for plant growth, an increase in soil moisture increases the number and the size of the plants and consequently the ratio of vegetation to bare soil becomes greater. Thus, an enhancement of the reflectivity in the near infrared band is observed in wet soils during the dry months of the year.

In the false color additive photographs, taken over Greece during the month of August, poorly drained soils and well irrigated soils show a bright red color. They can be separated, however, from each other from their spatial distribution and from the differences in the texture and in the shape of the respective areas, that they cover on the photograph.

1.3.4. Geomorphological Features of the Soils.

Important soil characteristics such as parent material, relief erosion, drainage, stage of development and productivity are related to geomorphology.

The black and white and false color composit photographs can be used for the classification of the geomorphological features. The best imagery for this purpose was the infrared black and white and the false color composit.

The following three classes, important from the soil's point of view, were recognized in the above 1:1000,000 scale imagery:

(1) Mountain slopes.

(2) Gently sloping tertiary deposits.

(3) Flat recent alluvial plains.

The above classes were recognized from their characteristic textures in the photographs. The mountainous regions characterized by deep and large valleys, gullies and falts were easily recognized. The separation of the tertiary deposits from the recent alluvial plains was made by the use of microscopic stereoscope. The tertiary deposits are located on higher elevations than the recent alluvial deposits. Erosion has caused, on the tertiary deposits, the formation of a network of gullies, which vary in size and orientation. This network dissects the tertiary deposits and produces a characteristic texture which in many cases can be seen on the 1:1000,000 scale photograph by the use of a magnifying stereoscope. The recent alluvial deposits are flat and thus lack the erosional paterns of the tertiary deposits.

The three geomorphological classes can be used in reconnaissance soil classification and mapping.

On the mountain slope form residual soils characterized by erosion hazzards, depth limitations and low productivity.

The tertiary deposits are the parent material of deep soils with well developed horizons,moderately eroded and in many cases calcareous. These soils are used for dry farming. Their agricultural value is moderate to low.

The recent alluvial soils are young in age, calcareous and they lack in well developed horizons. They are the best suited soils for intensive agriculture.

The photographic imagery provided by ERTS - 1 was used in correcting the boundaries of soils developed on tertiary and recent alluvial deposits in the 1:1000,000 scale soil map of Greece, which is now under preparation.

2. Analysis of Digital Imagery

2.1 General Background

Digital MSS data from the frames:

ERTS -1010 - 08375 (Eastern Peloponnese)

ERTS -1010 -08373 (Central Greece)

were received so far.

These data were reformated and processed by the IBM System/360 Model 44 Computer at LARS, Purdue University. The LARSPLAY and the LARSYSAA programs were used for the processing of the data.

The purpose of this investigation was to recognize and map land features on a more detailed scale, since the computer prints of digital information have higher resolution compared to the photographic imagery.

Feature vectors were analyzed and classified into 15 spectral classes by the LARSYSAA program. Computer maps were made for the above two provinces of Greece by assigning alphnumeric symbols to each of the classes.

A more detailed study of the above fifteen classes was conducted in the Kopais plain, where sufficient ground truth data were collected during the month of August of 1972

The Kopais plain is located about 70 miles North West of Athens. It consists of a drained lake bed, which is primarily used for irrigated agriculture. The plain is surrounded by hills consisting of limestone rock outcrops with sparse vegetation and of tertiary and quaternaly deposits, which have areas of shrubs and trees intermixed with fields of non irrigated winter crops.

The spectral classes of the Kopais plain were spatially checked with ground truth data. Their spectral signatures were also studied and visible / infrared ratios of reflected energy were calculated. On the basis of spectral and spatial properties land features were assigned to the classes as following:

2.2. Spectral and Land Use Classes

The spectral characteristics of the spectral classes of the Kopais plain are given in table 2.

Table 2. Characteristics of the spectral Classes of the Kopais plain.

Spectral class	Total Energy λ (μ) 0,50 - 1,10	% Energy at λ (μ) 0,50 - 0,70	% Energy at λ (μ) 0,70 - 1,10	Ratio $\frac{\%\ 0,50 - 0,70}{\%\ 0,70 - 1,10}$
1 / 15	201.31	54.85	45.15	1.215
2 / 15	167.47	32.96	67.03	0.492
3 / 15	155.26	37.35	62.64	0.596
4 / 15	163.51	46.58	53.41	0.872
5 / 15	145.45	44.11	55.88	0.787
6 / 15	168.78	54.23	45.77	1.185
7 / 15	152.31	53.56	46.44	1.153
8 / 15	138.09	53.97	46.02	1.173
9 / 15	147.57	50.10	49.89	1.00
10/15	136.86	39.24	60.75	0.645
11/15	134.36	49.39	50.60	0.976
12/15	126.07	42.42	57.57	0.737
13/15	123.82	51.35	48.64	1.056
14/15	109.14	52.54	47.45	1.107
15/15	63.29	75.25	24.74	3.041

The modality of the histograms for each class and channel is shown in table 3. The classes can be characterized as unimodal except for the classes 4 and 14, which could be split into two subclasses.

Table 3. Modality of the Histograms.

Spectral class	Channels			
	1	2	3	4
1/15	unimodal	bimodal	unimodal	unimodal
2/15	uni -	uni -	bi -	uni -
3/15	uni -	uni -	bi -	uni -
4/15	uni -	bi -	uni -	bi -
5/15	uni -	uni -	uni -	uni -
6/15	uni -	uni -	uni -	uni -
7/15	uni -	uni -	uni -	uni -
8/15	uni -	uni -	uni -	uni -
9/15	uni -	uni -	uni -	uni -
10/15	uni -	uni -	uni -	uni -
11/15	uni -	bi -	uni -	uni -
12/15	uni -	uni -	uni -	uni -
13/15	uni -	bi -	uni -	uni -
14/15	uni -	bi -	bi -	bi -
15/15	uni -	uni -	uni -	uni -

2.3. Land Use Classes

On the basis of ground truth data and their spatial and spectral characteristics the fifteen classes were assigned to eight land use classes as it is shown in table 4.

Table 4. Correspondence of Spectral to Land Use Classes.

Land Use Classes	Spectral Classes														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Corn										+		+			
2. Wheat							+								
3. Alfalfa		+													
4. Trees-shrubs									+		+		+	+	
5. Cotton			+												
6. Unknown				+	+										
7. Soil						+		+							
8. Eroded Soil	+														
9. Water															+

Table 4 shows that in many cases more than one spectral classes had to be grouped into one land use class. This was necessary because land use subclasses were not spatially separable and it was, to some extend, justified by the proximity of the spectral ratios of the grouped spectral classes shown in table 2.

The modality of the land use classes was tested from the histograms, which were calculated by the statistics of the LARSYSAA program. The results of these calculations are shown in table 5.

Table 5. Modality of the Land Use Classes.

Land Use Class	Spectral Channels			
	1	2	3	4
1. Corn	unimodal	unimodal	unimodal	unimodal
2. Wheat	uni-	uni-	uni-	uni-
3. Alfalfa	uni-	uni-	uni-	uni-
4. Trees-shrubs	uni-	uni-	uni-	uni-
5. Cotton	uni-	uni-	bi-	uni-
6. Unknown	bi-	bi-	bi-	uni-
7. Soil	bi-	bi-	bi-	bi-
8. Eroded Soil	uni-	uni-	uni-	uni-
9. Water	uni-	uni-	uni-	uni-

The most reflective spectral class 1 was assigned to soils with light colored surface. The parent material of the drained lacustrine soil is a whitish marl. Upon oxidation of the thin organic surface layer and deep ploughing, the marl was brought to the surface of the soil in many locations. This soil surface has the highest total reflectivity of all the other surfaces in the studied area. The reflected energy in the visible part of the spectrum is greater than in the infrared due to the lack of vegetation cover. This land use class was named "eroded soils" and it is found both on the marly bottom land and on the eroded slopes of the tertiary deposits.

The spectral classes 6 and 8 were assigned to the bare soil surface. From these two classes the first has higher total reflectivity than the second one. Their spectral ratios, however, are about the same. The modality in table 5 also indicates that two bare soil surfaces can be recognized.

Indeed ground truth data have shown that the brighter spectral class 6 should be assigned to flat bare soil surfaces of the bottomland in areas where the marly parent material has not been exposed. Class 8 should be assigned to the rocky surfaces of the surrounding the bottomland hills. These hills have the limestone bedrock exposed on the greater part of their sloping surfaces. The vegetation is sparse and it was mostly dry during the acquisition of the spectral data by ERTS - 1.

The roughness of the surface and the presence of dry vegetation could possibly explain the lower reflectivity of spectral class 8 as compared to spectral class 6.

The recognition, separation and mapping of the above three classes of soil can be regarded as a significant achievement toward the assesment of the productivity of the studied area. Thus spectral class 6 corresponds to highly productive soil, spectral class 1 corresponds to soils of low productivity and spectral class 8 corresponds to unproductive soil.

Spectral class 7 was assigned to wheat fields. In August, at the time that the data were recorded by ERTS - 1, the wheat fields had been harvested and only a short dry straw remained on the ground. Thus bare soil constituted a large portion of the reflecting surface. Accordingly the spectral data (table 2) of class 7 do not deviate significantly from those of the classes 6 and 8, which were assigned to bare soil. Due to the uniform distribution and the minuteness of the soil and straw surfaces, the whole reflecting surface appears uniform. For this reason the respective histograms are narrow.

Spectral classes 2 and 3 were assigned to alfalfa and cotton respectively. Both classes are characterized by low spectral ratios. Both crops were irrigated and thus were highly reflective in the infrared wave lengths. However, during the month of August alfalfa fields present a denser and a greener surface than cotton fields. Consequently alfalfa has a smaller spectral ratio than cotton.

The unknown land use class consist of greatly fragmented fields of various irrigated crops intermixed with wheat fields, bare soil trees and shrubs. Due to the small size of the fields ,the resolution was poor and the separation was not feasible. The variability in the spectral signatures of this land use class is also reflected in the histograms, which are distinctly bimodal. The spectral classes 4,5 and 9 were assigned to this land use class.

Corn fields covered a large area in the irrigated bottomland. Two spectral classes were associated with the cornfields: class 10 and class 12. As it can be seen in tables 2 and 4 the two classes have similar characteristics and the histograms of the land use class are unimodal.

At the time of the spectral recording by ERTS - 1, corn was approaching maturity and irrigation was not as intensive as for alfalfa and cotton. Thus the relative reflectance of corn in the infrared region was somewhat lower than that of the other two crops.

Spectral class 10 has lower ratio than class 12. The difference may be attributed to variations in irrigation and in the maturity stage of the crop.

The land use class trees and shrubs covers the surrounding hills of the Kopais plain. This land use class is characterized by brocken forest and shrub vegetation growing on soils developed on tertiary and quaternary deposits as well as on soils developed on limestone. The depth of the soil is adequate for the growth of vegetation. Its moisture regime, however, is not favorable. In small scattered areas, the native vegetation has been cleared out and the land is used for dry farming.

A number of these farms have been abandoned.

The spectral classes which were associated with this land use class were the 11, 13 and 14. These three classes differ in their total reflectivities but the reflected energy is about equally distributed between the visible and the infrared range in all of them. Thus, the spectral ratios approach unity, a value which lies between that of the bare soil and the green vegetation.

Water is characterized by low reflectivity, especially in the infrared range. Spectral class 15 was therefore the appropriate one to be assigned to water, which was in complete agreement with ground truth data.

2.4. Land Use Mapping.

Training fields were selected on the computer printout of the spectral classes taking into consideration ground truth data. Then the computer was instructed to print a land use map where the nine classes were represented by alphanumeric symbols.

A threshold of 0,5% was used in the grouping of the spectral features into land use classes.

The training class performance is shown in table 5. The printed land use map was checked against land use ground truth data and it was found satisfactory. The scale of the map was about 1:22.000.

Blank areas on the map correspond to the threshold and they represent mostly residential areas.

Table 5. Training Class Performance for the Kopais Plain

Class	No. of samples	Pct correct classification	Number of samples classified into:								
			Corn	Wheat	Alfalfa	Trees	Cotton	Unknown	Soil	Er.Soil	Threshold
1. Corn	468	96.8	453	0	0	0	1	14	0	0	0
2. Wheat	248	91.1	0	226	0	0	0	1	20	0	1
3. Alfalfa	98	94.9	0	0	93	0	2	3	0	0	0
4. Trees-shrubs	345	98.0	0	0	0	338	0	0	0	0	7
5. Cotton	75	97.3	0	0	0	0	73	0	0	0	0
6. Unknown	84	98.8	0	0	0	0	1	83	0	0	0
7. Soil	110	95.5	0	0	0	4	0	0	105	1	0
8. Eroded Soil	136	97.1	0	0	0	0	0	0	0	132	4
Total	1564		453	226	93	342	77	101	125	133	12

Overcall Performance (1503 /1564) = 96.1%

Average Performance by class (769.4 /8) =96.2%

3. Other Studies

Computer printed maps showing the distribution of the fifteen spectral classes in selected areas of Central Greece and Peloponnese were made at LARS.

Preliminary studies on these maps have resulted in the recognition of the following land features:

a. Residential areas: streets, parks, cemeteries and airports.

b. Rural areas: forests, agricultural lands, idle lands and bare soil.

c. Water: two spectral classes have been recognized for sea water,most probably related to the depth of water along the shore line.

CONCLUSIONS AND SUMMARY

Photographic and digital imagery of Central Greece and Eastern Peloponnese were analyzed.

On the basis of information extracted from black and white and false color composit phtographic imagery and spatial information the following land use classes were recognized and mapped:

a. Forests: dense and thin stands of fir-austrian pine and halepo pine.

b. Shrubs and idle land: dense shrubs, thin shrubs and rocky idle lands.

c. Agricultural lands: well irrigated and marginally irrigated crops, winter farmland, olive groves and vineyards.

The accuracy of the above maps was satisfactory.

Photographic imagery and photographs printed from digital data by the computer were used to recognize and map the following soil classes:

Recent alluvial soils, tertiary soils eroded residual soils, wet soils and saline soils.

False color composits made through additive process from RBV and MSS 1:100,000 scale photographic images were used to identify and map agricultural forest and range site evaluation classes based on the water supplying capability of the soil. Forest and range site mapping covering large areas was not done in Greece previously.

The ERTS - 1 project has provided extremely valuable information for this task.

Digital data from the Kopais plain were analyzed at LARS by the use of LARSYSAA computer program. Fifteen spectral classes were assigned to nine detailed crop, semidetailed soil and water classes. Alphanumeric computer maps of about 1:22,000 scale were printed showing the distribution of these nine classes. These maps provide information on the degree of proper utilization of land resources in the study area.

The feature recognition patterns, which were developed in this investigation, are strongly influenced by the local ecological, spatial and land parameters. Thus the results found and the techniques proposed in this report may have applications to areas of ecological land and agricultural conditions similar to those of south-eastern Greece.-

APPENDIX

Land Use Map of East Peloponnese

Land Use Map of Central Greece

Site Evaluation Map