ISTANBUL TECHNICAL UNIVERSITY ★ INFORMATICS INSTITUTE

UNIFYING REMOTE SENSING AND WEB GIS INFRASTRUCTURE DESIGN AND IMPLEMENTATION OF WEIGHTED OVERLAY ANALYSIS ON VEGETATION INDICES

M.Sc. THESIS

Barkın KOCAL (706121019)

Informatics Institute

Geographical Information Technologies Programme

Thesis Advisor: Assoc. Prof. Dr. M. Tevfik Özlüdemir

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ BİLİŞİM ENSTİTÜSÜ

UZAKTAN ALGILAMA VE WEB CBS ALTYAPI TASARIMININ BİRLEŞTİRİLMESİ VE BİTKİ ÖRTÜSÜ ÜZERİNDE ÇOK KATMANLI AĞIRLIKLI ÇAKIŞTIRMA ANALİZİNİN UYGULANMASI

YÜKSEK LİSANS TEZİ

Barkın KOCAL

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Barkin KOCAL, a M.Sc. student of ITU Informatics Institute, student ID: 706121019 successfully defended the thesis entitled "UNIFYING REMOTE SENSING AND WEB GIS INFRASTRUCTURE DESIGN AND IMPLEMENTATION OF WEIGHTED OVERLAY ANALYSIS ON VEGETATION INDICES", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 08 May 2017

Date of Defense : 06 June 2017

In memory of Captain Tülin Karabudak and Özgen Metin,

FOREWORD

I wish to thank, first and foremost, my supervisor, ***Assoc. Prof. Dr. M. Tevfik ÖZLÜDEMİR*** for his advice, guidance and most of all, for supporting me to study on this wonderful and exciting topic as thesis subject.

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June 2017 Barkın KOCAL (MSc. Student)

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ABBREVIATIONS

ITU : Istanbul Technical University
GIS : Geographic Information Systems
WMS : Web Map Service
WPS : Web Processing Service
OGC : Open Geospatial Consortium
DBMS : Database Management System
XML : Extensible Markup Language
WOA : Weighted Overlay Analysis
VI : Vegetation Index
UAV : Unmanned Aerial Vehicle
CI : Chlorophyll Index

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UNIFYING REMOTE SENSING AND WEB GIS INFRASTRUCTURE DESIGN AND IMPLEMENTATION OF WEIGHTED OVERLAY ANALYSIS ON VEGETATION INDICES

SUMMARY

Development momentum of satellite technologies;

- enables us tracking seasonal changes in vegetation regionally or globally via remote sensing phenology,
- leads us observing the invisible light spectrum and its meanings inside.

As living in information age, people have started to understand mathematical chains through the nature and environment. We get values identified by sensors as inputs, write functions for various analysis that helps us to visualize and figure out of enhanced outputs from raw imagery.

This thesis study concentrates on the topic of GIS and remote sensing using a multispectral imaging system for vegetative research and its use mainly in agricultural applications. Applications may be used for classification of the forests, change detection on burned area, site selection of specific varieties of agricultural goods, acquiring the health or stress level of vegetation, resource optimization along with sustainable environment and more else with researchers vision.

'Spectr-Agri-ITU' app is a GIS based modelling, geo-design collaborated web app which spectrally transforms the raw imagery into valued information.

The input must be an image containing red, green, blue (RGB), near infra-red (NIR), and shortwave infrared (SWIR 1-2) spectral bands. Otherwise some analyzes will not work. Spectral imagery use for vegetation manner is mainly based on red and infrared light because of reflectance and scatter. Selectable analysis and indices which user may specify, applied to uploaded spectral image. Mostly known and used analysis is normalized difference vegetation index (NDVI) which is a key for quickly identifying vegetated areas and their "condition," and it remains the most used index to detect live green plant canopies in multispectral remote sensing data. There are more vegetation indices which are mathematical combination or transformation of spectral bands that emphasize the spectral characteristics of greenness.

Enhanced imagery is created as numerous raster data, presents information for next step. Weighted overlay analysis (WOA) provides us to associate, weight and rank various types of information so to evaluate multiple factors at once. Percentage settings of weights form the final output.

Finally output raster data has meanings to visualize with smart mapping styles, color ramps and symbology. Customizable styles let user to understand spectral imagery insights of research.

This innovative application puts these cut-edge technologies forward in World Wide Web environment with Web-GIS architecture.

UZAKTAN ALGILAMA VE WEB CBS ALTYAPI TASARIMININ BİRLEŞTİRİLMESİ VE BİTKİ ÖRTÜSÜ ÜZERİNDE ÇOK KATMANLI AĞIRLIKLI ÇAKIŞTIRMA ANALİZİNİN UYGULANMASI

ÖZET

Uydu teknolojilerindeki ivme kazanan gelişim;

- Uzaktan algılama fenolojileriyle bitki örtüsünün dönemsel değişimlerini, bölgesel ve küresel olarak takip edebilmemizi sağlamış,
- Görünmez ışık spektrumunun gözlemlenmesi ve içerdiği anlamın çıkarılması konusunda ufkumuzu açmıştır.

Bilgi çağında yaşamaya başlayan günümüz insanları doğa ve çevre arasındaki zincirin matematiksel bağları anlamaya başladı. Sensörler tarafından tespit edilen değerleri girdi verisi olarak kullanıyor, ham görüntüleri görselleştirmemize ve yeni anlamlar çıkarmamıza yardımcı olan çeşitli analizler için fonksiyonlar yazıyoruz.

Bu tez çalışması Coğrafi Bilgi Sistemleri (CBS) ve uzaktan algılama teknolojileriyle bitki örtüsü araştırmaları ve başlıca tarımsal uygulamaları için multispektral görüntüleme sistemleri kullanımı konularına yoğunlaşmaktadır. Uygulama, ormanların sınıflandırılması, yangın alanlarında değişim tespiti, özelleştirilmiş çeşitli tarımsal ürünler için yer seçimi, bitki sağlığı veya stres düzeyi, kaynak iyileştirmesiyle birlikte sürdürülebilir çevre ve araştırmacının vizyonuyla birlikte niceleri için kullanılabilir.

Spect-Agri uygulaması, CBS tabanlı modellenen, geo-design tasarımlı, ham görüntüyü spektral olarak değerli bilgiye dönüştüren bir web uygulamasıdır.

Girdi, kırmızı, yeşil, mavi (RGB), yakın kızıl ötesi (NIR) ve kısa dalga kızılötesi (SWIR 1-2) spektral bantlarını içeren görüntü olmalıdır. Aksi durumlarda bazı analizler çalışmayacaktır. Bitki örtüsü konusuna ilişkin çalışmalar, yansıma ve dağılmasından dolayı çoğunlukla kırmızı ve kızıl ötesi ışığı ile yapılmaktadır. Kullanıcının belirlediği seçilebilir analizler ve indeksler, web'e yüklenen multispektral görüntüye uygulanır. En çok bilinen ve kullanılan analizlerin başında gelen normalleştirilmiş fark bitki örtüsü indeksi (NDVI), bitki örtüsünün bulunduğu alanların ve "durumlarının" hızlıca tanımlanması için ana unsurdur ve bitki örtüsünde canlı yeşil rengi saptama konusunda en çok kullanılan olarak kalacaktır. Günümüzde çok sayıda ve özelliklerde, yeşilliliğin spektral özelliklerini matematiksel kombinasyon veya spektral bantların değişimiyle vurgulayan bitki örtüsü indeksleri bulunmaktadır.

Çoklu raster verisi halinde oluşturulan zenginleştirilmiş görüntü, sonraki adım için bilgiler sunmaktadır. Çok katmanlı ağırlıklı çakıştırma analizi (Weighted overlay analysis - WOA), çeşitli türde bilgilerin derecelendirilmiş ve ağırlıklandırılmış çoklu faktör ve parametrelerle değerlendirilerek birleştirilmesini sağlamaktadır. Belirlenen ağırlık yüzdeleri son çıktıyı etkilemektedir.

Son olarak, çıktı raster verisine, akıllı haritalama stilleriyle, renk rampalarıyla ve sembolojileriyle görselleştirilmeye hazır şekilde yeni anlamlar kazandırılmaktadır.

Tarım, orman, biyoloji, botanik vb. bitki örtüsü hakkında çalışan araştırmacılar, bilim insanları, öğrenciler, bilimsel tarım uzmanları 'Spectr-Agri-ITU' uygulaması ile web üzerinden analiz yapabilecektir. Çağı takip eden, araştırmalarında CBS ve uzaktan algılama uygulamalarını konumlandıracak vizyondaki bilim insanlarına yardımcı olmak ve birlikte bu aracı geliştirmek amaçlanmaktadır.

Bu yenilikçi uygulamanın, World Wide Web çevresiyle birlikte Web-CBS mimarisi içerisinde, bitki ve yeşillilik konusunda küresel yönelimler doğrultusunda oluşturulması amaçlanmıştır.

1. INTRODUCTION

Living in the third great social revolution, first was agricultural, second was industrial, lastly informational revolution gave people the chance to implement new technologies in our conventional activities and habits.

Satellite technologies and remote sensing imagery has risen up and provided observations on the Earth and universe with new perspective which have never been experienced. Imagery via red, green, blue bands (RGB) is called true color imagery, because human eye can see this spectrum of light. The rest of the spectrum is called invisible light spectrum.

Electromagnetic spectrum lines long wavelength as Radio Waves through the short wavelength as Gamma rays. These nano-metric wavelengths extract information from elementally structures to dynamically changing behaviors. Changes on chlorophyll amount, released nitrogen amount, color pigment may intercept the hidden invisible information.

The outputs may indicate ways of efficient production and sustainable environments or to prevent forest fires, spread of diseases, etc.

Our conventional agricultural methods and activities depend on personal, cultural and regional phenomenon. This way seems logical in low scaled operations. As it exists through the generations' knowledge, it is also fragile by unexpected parameters. As people are touching the environment in global scale, global trends and patterns should be considered with habits and behaviors.

Global warming and erosion caused by human activities are accelerating thereby traditional knowledge and habits which are lack of science is faced up being useless. The practice of precision agriculture has been enabled by the advent of GNSS. Crop production efficiency is becoming more important due to population increasing speed. Agriculturists need to correspond future demands by today's analyses. Crop vegetation control and crop yield forecasting are day by day become highly critical issues.

Geosciences' goal is to understand Earth's history and its future, the resources required to assist the increasing global population, and the challenge of sustainability in a fast changing climate.

Geographic information technologies enabled people to analyze spatial bonding, patterns and trends between disciplines in a system. Geographic information system (GIS) is an inter-disciplinary way of collaboration to question, analyze, visualize and interpret the insights of spatial data.

GIS is improving and developing through World Wide Web environment naturally. Global needs shape the trends dramatically to share, reach and progress, independent from desktop software, hardware and throughput.

These multi-disciplinary manners and more to come, need platform to collaborate and understand each other seamlessly. 'Spectr-Agri-ITU' is envisioned to follow and forward todays needs with futures thoughts. Its projection is to be capable of enhance by the standards which are globally accepted.

1.1 Aim of the thesis

State of art technologies has a significant role for managing the natural resources, improving awareness of operations, developing sustainable environments due to the earth observations. Crop monitoring is one of the main agricultural applications since remote sensing provides us accurate, most recent and cost-effective information about the various crops at the different temporal and spatial resolution.

A vegetation index is a single number that quantifies vegetation biomass and/or plant vigor for each pixel in a remote sensing image. The index is computed using several spectral bands that are sensitive to plant biomass and vigor. Using this valued information via web GIS architecture is a way of helping and developing with multi-disciplinary manners.

This thesis study aims to make a geographical information system based application which can run on the web, known as Web-GIS technology that can provide accessible and easy to use platforms to people. With this application, users can specify indices, customize weights and ranks for specific purposes.

Researchers, scientists, students, agronomists who works or studies on -agriculture, forestry, biology, botanic, etc.- shortly based on vegetation will use ‘Spectr-Agri-ITU’ app. Scientists who have vision to implement GIS and remote sensing on their research gain access to have insights of this multi-disciplinary topic.

1.2 Methodology

This section of the thesis consists of Literature Review and development of application stages.

1.2.1 Literature review

Development of satellite technology enabled us to see the world from another perspective. As Schowengerdt (2007) mentioned that a multispectral image is one that captures image data at specific frequencies across the electromagnetic spectrum. Spectral imaging can allow extraction of additional information like infrared, the human eye fails to capture with its receptors for red, green and blue. It was originally developed for space-based imaging.

Aerial remote sensing and mapping that, for some years now, has been serving the needs of large-scale low-altitude imaging and geospatial information users and developing an industry of its own (Cho et al., 2013).

Remote sensing technologies have been improving since the 1960’s and our understandings get deeper. Unmanned Aerial Vehicles (UAV) and drones with integrated cameras are able to carry spectral sensors and also some spectral filters and are easy to use and affordable even for personal use.

Perhaps, we are passing right in front of the future, by the pioneering case of Trinidad and Tobago, where the government has already issued a tender for an UAV system “to provide colored map and imagery products to serve the identical purpose of conventional aerial survey and to satisfy the needs of a demanding spatial data market.” Government of the Republic of Trinidad and Tobago. (GORTT, 2013)

Digital era in the imagery and mapping provided researchers to analyze images with mathematical functions.

Visualizing the problems as functions, brings spatial analysis power with GIS. Wise use and selection of these functions will lead to high quality of the information produced from the GIS. Individual analysis functions must be used within the context of a complete analysis strategy (Healey, 1993).

Visible red, green, and blue band and near-infrared (NIR) regions of the electromagnetic spectrum have been used successfully to monitor crop cover, crop health, soil moisture, nitrogen stress, and crop yield (Lillesand, Keifer, 1994).

The strong contrast of absorption and scattering of the red and near-infrared bands can be combined into different quantitative indices of vegetation conditions. These mathematical quantitative combinations are known as vegetation indices. Normalized difference vegetation index (NDVI) is the most commonly known index. Also combinations of different indices and layers such as moisture, mineral, slope, sun approach angle and period, etc. integrated with each other give insights of information.

Numerous studies have been conducted on crop growth analysis using normalized difference vegetation index (NDVI) to support precision agriculture. Most widely used methods and published literature associated with analyzing NDVI, only require Near-Infrared and Red spectral bands. Most vegetation indices combine information contained in these two bands.

Normalized burn ratio index (NBR), normalized difference moisture index (NDMI), and soil adjusted vegetation index (SAVI) are the main items in the Spectr-Agri-ITU application, but not limited to them for future discussions.

High vegetation cover could increase the thermal landscape heterogeneity and the aggregation among different landscapes, and promote the energy exchange between the lower temperature patches and higher temperature patches, playing an important role in controlling hot island effect. NDMI and vegetation cover had the same effects on the formation of thermal landscape pattern. (Wang, Guan, 2012)

NDMI is used by different studies such as McCullough and Bain mentioned in 2015, derived from Landsat imagery was applied to expose patterns of vegetation water stress, which were then compared across a temporal gradient of mined panels. NDMI values associated with panels from 2000 through 2014 were assessed. NDMI explains mining impacts to forest canopies and the landscape features driving patterns of tree canopy moisture content

Huete, A. R., (1988) study shows that, the conversion technique presented in the study is an important step towards the creation of simple global models that can adequately describe dynamic soft vegetation systems. The SAVI is a method in which ground substrate variations are effectively normalized and vegetation coverage is not affected by providing spectral indexes to be refined or "calibrated".

Normalized burn ratio index is a greenness index which normalizes the reflectance of near-infrared and mid-infrared to monitor fire affected areas (Lopez Garcia and Caselles 1991; Key and Benson 2006). In the study by Lopez Garcia and Caselles (1991), NBR was used to detect vegetation regeneration in three burnt areas using six years of post-fire images. The difference of NBR is calculated using the difference between pre-fire and post-fire NBR values indicates in equation. (Chen, et al., 2011)

Heilman and Kress (1987), investigated the differential rates of radiant flux penetration in incomplete cotton canopies and found the spectral response reflected from the soil surface to mimic that of green vegetation. Thus, regardless of the vegetation index tested, the soil-reflected signal was indistinguishable from that of the vegetation. The soft component rendered vegetation indices "soft-dependent" because its magnitude varied with the reflectance properties of the underlying soil.

According to Huete et al., (2002) two plants are routinely produced from the MODIS sensor. For this research, they chose enhanced vegetation index EVI instead of the commonly used normalized vegetation index of NDVI. EVI is less susceptible to soil and atmospheric effects than NDVI because it contains blue spectral wave lengths. As a result, EVI continues to be more sensitive to increases in canopy intensity than where NDVI is saturated.

Chaoyang W., Zheng N., Shuai G. (2012) paper shows studies about the green chlorophyll index (GCI). It has been selected and tested for the estimation of mid-day LUE using cloudless MODIS (or Moderate Resolution Imaging Spectroradiometer) images with 500 m spatial resolution and corn flow measurements, which are mostly proposed for estimation of canopy chlorophyll content. CI-green is based on a conceptual model of reciprocal reflection that can isolate the absorption coefficient from the pigment reflection spectrum.

Vina, A., Henebry, G., M., Gitelson A., A., (2004) study shows that, a recent approach to improving plant cover index susceptibility in medium to high concentrations of green biomass has recently been suggested and demonstrated with the perception of wheat, corn and soybean canopies. They applied this approach to the image time series to assess whether it could provide improved sensitivity to productive vegetation surfaces compared to Advanced Very High Resolution Radiometer, AVHRR-NDVI. Vegetation indices (VI) were calculated from red and near-infrared AVHRR. Top-of-Atmosphere (TOA) reflectance as VI= (a* NIR- red / a * NIR + red) where a is a weighting coefficient. When a = 1, the equation yields the conventional NDVI formulation. when 0 < a < 1, the equation yields the WDRVI. With a < 1, the contribution from the NIR channel is attenuated, making it more comparable to the red channel values. This is especially important if the green biomass is significantly higher than medium red to NIR reflectance under medium to high density conditions. The specific size depends primarily on the sensor properties, the atmospheric conditions and the amount and type of vegetation cover.

As a simple fact, production of food is the main need of humankind society in every era of being. Optimizing the yield efficiency and understanding the parameters depend on are our species' essential. In crescent of human population forthcoming, thereby following lack of food and water resources are forcing us to optimize our deficient operations and methods. Adaptation of new technologies with conventional methods is not easy in practice and it requires wide perspective and collaboration.

After the creation of vegetation indices, they will overlaid on a specific weight analysis by importance of phenomenon. As Kabir (2013) mentioned that weighted according to a percentage of influence and combined to produce a map displaying suitable locations for the proposed areas, when he was researching on flood hazard management.

Transforming technologies for precision and sustainable farming systems have a multi-disciplinary character.

1.2.2 Application Model

Konya plain is selected as example multi spectral imagery, because of its agricultural production importance for Turkiye. Sample multi spectral raster is capture from lands which are lying between Karakaya, Başak, Hayıroğlu, mostly agricultural use of lands in Konya.

Images from different sources such as Worldview and SPOT have been tested.

Reference images are collected by Landsat satellites. Landsat satellite program is one the pioneers on satellite technology in variety of manners. Landsat 8 satellite has 8 bands, including visible and invisible spectrum. These 8 bands are suitable for Vegetation Indices which application creates. Images have 30 meter spatial resolution and they are free of charge.

Raw multispectral images are enhanced with band arithmetic and functions. These vegetation indices and analysis are globally recognized and operative on vegetative and agricultural researches.

Application's workflow is transforming raw imagery to analyze value outputs with customizable parameters.

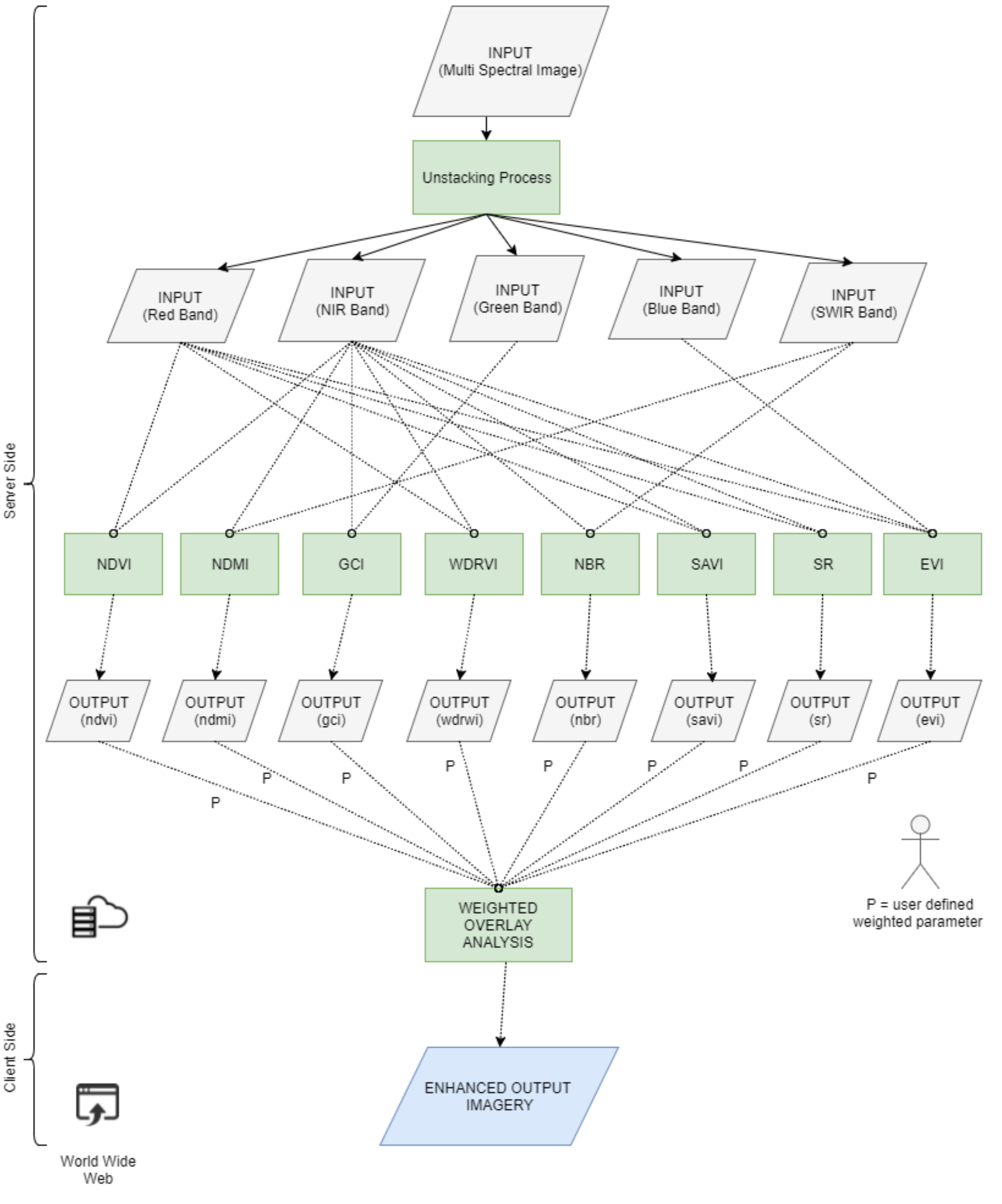

Figure 1.1 Processing Flow Chart

2. TECHNICAL INFORMATION

2.1 Remote Sensing

Nowadays, remote sensing satellite imagery is one of the basic requirements for land change identification, environmental and urban change analysis.

Remote Sensing has many definitions and it has been used in many disciplines.

Remote sensing is the process of collecting data in a non-contact manner from objects. This study's main scientific planch is based on remote sensing. Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

Another definition of remote sensing is that, it is a technique of obtaining information about and evaluating the natural and artificial objects of the earth without passing physical objects to objects with measuring instruments placed on platforms moving at a certain distance from the earth, in the atmosphere or in space (Sesören, 2016).

Remote Sensing is heavily used by a large number of scientists. The areas where Remote Sensing is used can be listed as follows:

- Agriculture, forestry and botany
- Glacial knowledge
- Geology, geomorphology and geodesy
- Meteorology
- Military applications
- Natural disaster control
- Planning applications

- Topography and cartography

One of the most important application areas where remote sensing technologies are used is the observing of agricultural changes by determining agricultural land cover and/or agricultural variety observation with satellite images. Determination of agricultural land cover and/or its use is extremely important in terms of protection of the natural environment in case of planning and food production. The most important advantages of remote sensing technologies are the ability to use images with different spatial, radiometric, spectral, and temporal resolutions. Therefore, remote sensing applications have many advantages according to satellite image quality.

2.1.1 Basic Components of Remote Sensing

There are five basic components of remote sensing:

- Energy source.
- Interaction of the energy in the atmosphere.
- Interaction with the earth.
- Recording of energy as a data by a sensor.
- Display of the data for visual-numerical analysis.

With remote sensing technologies, the first requirement for the perception of objects on the earth is to have an energy source to illuminate the target unless the perceived energy is spread from the target. It is shown in figure 2.1. The most important energy source in remote sensing is the sun. Electromagnetic energy reaches the earth as electromagnetic waves. Light is an energy and reaches the earth in the form of electromagnetic waves from the sun. This energy is in the form of electromagnetic radiation. In remote sensing, the transport of energy through radiation is referred to as electromagnetic radiation (Çölkesen, 2009).

With this electromagnetic radiation, the spectral cameras located on the satellite record the corresponding spectral values of the object and transmit them to the satellite earth stations. Satellite earth stations are provided for end users to use in different application areas.

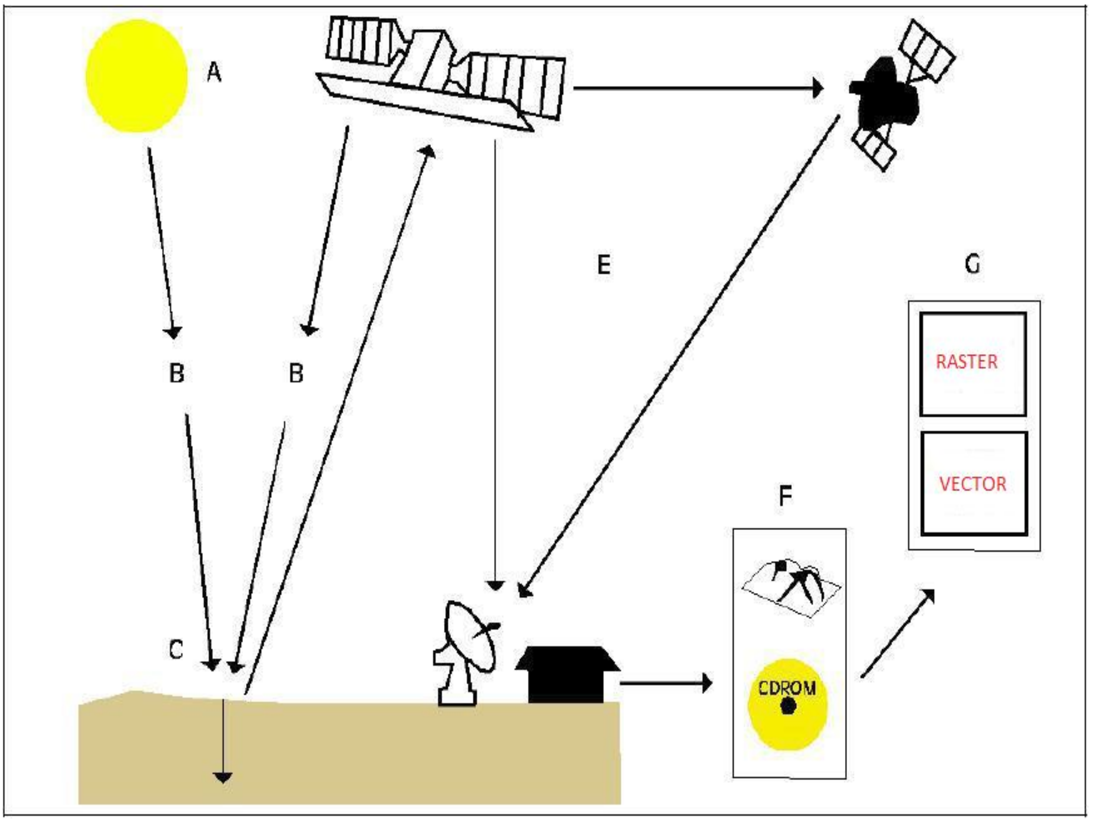

Figure 2.1: Remote Sensing Workflow, A: Energy source (EMR), B: Radiation and atmosphere, C: Interaction with the target, D: Energy storage by the sensor, E: Transmission and processing, F: Interpretation and analysis, G: Application. (Sesremo, 2016).

There are two types of sensors, passive and active. A passive sensor system needs an external energy source. In most cases this source is sunlight. These sensors usually detect the energy wavelengths that are reflected and propagated in a phenomenon. An active sensor system provides its own energy source. For example, a radar sensor sends sound waves and records the reflected waves back from the surface. Passive systems are much more common than active systems.

Most sensors record information about the Earth's surface by measuring the energy from the surface in different parts of the electromagnetic (EM) spectrum (Figure 2.2). Since the surface of the earth changes in nature, the transmitted energy also changes. This change in energy allows the creation of images of the surface. Human eyes see this change in energy in the visible part of the EM spectrum. Sensors detect energy variations in both visible and invisible areas of the spectrum. Energy waves in certain parts of the EM spectrum pass easily through the atmosphere; other species do not.

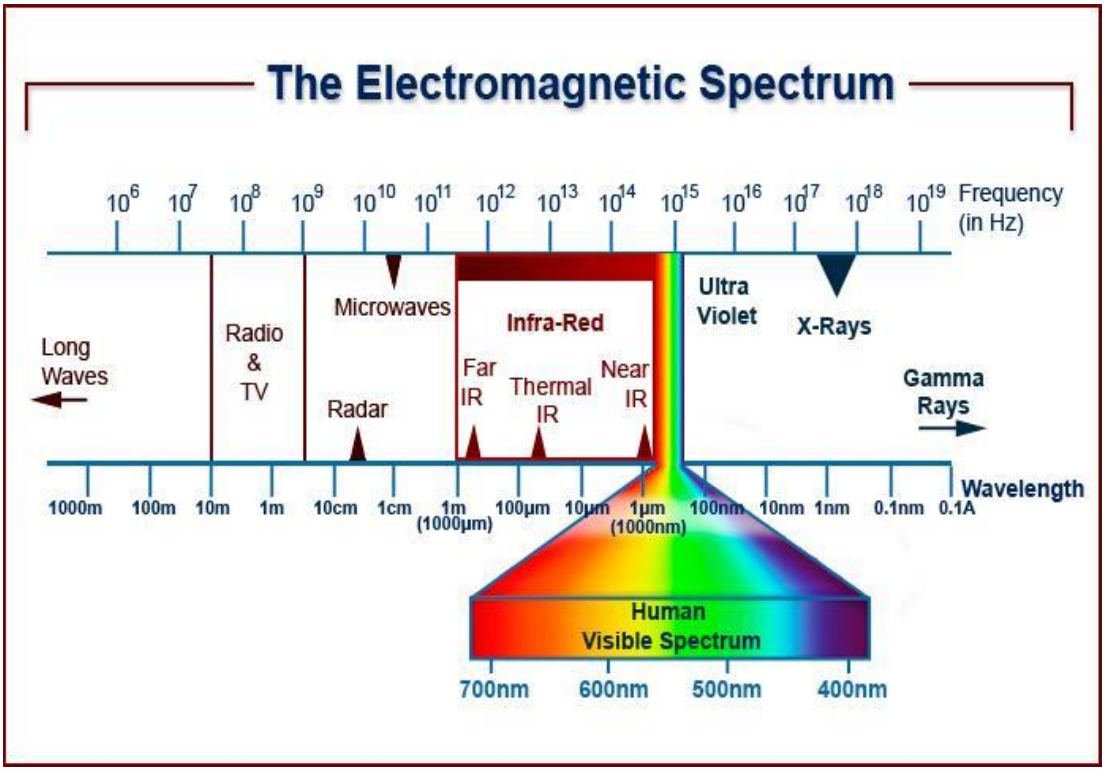

Figure 1.2 Electromagnetic Light Spectrum, adapted from (Clive R. Haynes).

The ability of the atmosphere to allow the passage of energy is called its permeability and depends on the wavelength of the radiation. The gases that make up the atmosphere allow the passage of energy with different wave lengths when sucking up energy in certain wave lengths.

2.1.2 Remote Sensing Phenology

Monitoring phenology at a global, regional or national scale is recognized by the scientific community as very important for many practical applications and notably for climate change studies. Analysis of spatial and temporal variations in the beginning and the end of the growing season can be used for example to determine regional variations and trends of the change in temperature and precipitation regimes. In agriculture, the accurate monitoring of crop development patterns represents an important component of farm management since it allows assessing if the most critical stages of growth occur during periods of favorable weather conditions.

Phenological observations are classically realized for specific plant species in botanical garden, in small study areas or fields all over the world and sometimes date back to the 19th century.

Although these observations are very interesting for studying the trends in phenology over time and their driving factors, they are punctual and provide therefore only little information on the spatial variability. Remote sensing phenology is able to consistently generate estimates of the start, peak, duration, and end of the growing season over large areas. The elements of phenology that can be estimated from remote sensing are necessarily coarser than direct observations of individual plant phenology, such as bud burst or first leaf, but are rather summaries of the constituents of pixels and do not normally represent any one vegetation type (Bradley, 2003).

Many sensors carried aboard satellites measure red and near-infrared light waves reflected by land surfaces. Using mathematical formulas (algorithms), scientists transform raw satellite data about these light waves into vegetation indices. A vegetation index is an indicator that describes the greenness — the relative density and health of vegetation — for each picture element, or pixel, in a satellite image.

Vegetation phenology, the study of periodic life-cycle events and their relation to climate, characterizes the seasonal timing of vegetation growing seasons, canopy growth and senescence. The timing, rate and duration of these events are integral components in the study of global change and the carbon cycle through direct effects on vegetation photosynthesis, carbon sequestration and land–atmosphere water and energy exchange (Penuelas et al., 2009). Recent climate change is affecting global phenology patterns and trends, as seen through generally earlier spring onset and delayed end of the growing season (Delbart et al., 2008; Parmesan, 2007; Piao et al., 2008).

Although there is a widespread evidence supporting these observations, conflicting results regarding satellite derived phenology trends and the methods used to define phenology metrics have been under examination (White et al., 2009). This is due, in part, to the challenge of equating satellite remote sensing based vegetation indices to in situ phenology measurements (Schwartz & Hanes, 2009; Wang et al., 2005).

2.1.3 Vegetation Indices

2.1.3.1 NDVI

The Normalized Difference Vegetation Index (NDVI) is a standardized index allowing you to generate an image displaying greenness (relative biomass). This index takes advantage of the contrast of the characteristics of two bands from a multispectral raster dataset—the chlorophyll pigment absorptions in the red band and the high reflectivity of plant materials in the near-infrared (NIR) band.

NDVI is historically one of the first vegetation indices. It is a normalized ratio of the NIR (near infrared) and red bands (Rouse et. Al. 1974). NDVI formula is given in equation 2.1.

$$NDVI = (NIR - Red) / (NIR + Red) \tag{2.1}$$

where NIR and Red parameters are the pixel values from the near infrared band and red band, respectively.

This index output values are between -1.0 and 1.0.

2.1.3.2 NDMI

The Normalized Difference Moisture Index (NDMI) is sensitive to the moisture levels in vegetation. It is used to monitor droughts as well as monitoring the fuel levels in fire-prone areas. It uses NIR and SWIR bands to create a ratio designed to mitigate illumination and atmospheric effects.

This index is referred to as the NDMI, however, the term moisture is conventional and retained for lack of a better term. One reason a universally accepted term is lacking is because the biophysical interpretation of indices that use the MIR bands is more problematic than indices that use only red and NIR bands. Other factors such as emissivity, energy balance, forest structure, and forest cover must be considered (McDonald et al., 1998). NDMI formula is given in equation 2.2

$$NDMI = (NIR - SWIR1) / (NIR + SWIR1) \tag{2.2}$$

where SWIR1 stands for the pixel values from the short-wave infrared 1 band.

2.1.3.3 GCI

Plant photosynthesis process, absorption of light by the leaf can be known with the Green chlorophyll Index (GCI) as Janki (2015) mentioned in Esri UC. It has been used as a parameter showing the canopy greenness. GCI formula is given in equation 2.3

$$GCI = (NIR) / (GREEN) – 1 \quad (2.3)$$

where GREEN is the pixel values from the green band.

2.1.3.4 WDRVI

The Wide Dynamic Range Vegetation Index (WDRVI) is useful for discriminating land cover and land cover qualities. Gitelson (2004) introduced the WDRVI as a way to enhance the dynamic range of the NDVI by applying a weighting parameter alpha to the near infrared reflectance as given in the following equation (2.4).

$$WDRVI= (alpha\text{-}NIR - RED) / (alpha\text{-}NIR + RED) \; alpha = 0.1 \; s \quad (2.4)$$

If alpha equals 1, then the WDRVI is equivalent to the NDVI. If alpha equals (Red /NIR), then the WDRVI equals zero. Think of alpha as a tuning knob that adjusts the gain on the index. Selection of the coefficient for the alpha parameter requires some forethought.

2.1.3.5 NBR

The Normalized Burn Ratio Index (NBR) uses the NIR and SWIR bands to emphasize burned areas, while mitigating illumination and atmospheric effects. Your images should be corrected to reflectance values before using this index.

Each spectral band responds in unique ways to surficial characteristics such as water content, vegetation structure, productivity, and mineral composition. When brightness values of multiple bands are combined in mathematical algorithms, information about targeted features can be enhanced, isolated, and analyzed. From available raw data, the challenge is to develop a specific index providing an optimum measure and useful signal for fire-effects, given the available bandwidths to work with (Key & Benson, 2006). It is similar in construct to NDVI. The primary difference is that NBR integrates the two Landsat bands that respond most, but in opposite ways to burning.

The NBR is calculated as in the following equation 2.5:

$$NBR = (NIR - SWIR) / (NIR + SWIR) \quad (2.5)$$

where SWIR is the pixel values from the short-wave infrared band.

2.1.3.6 SAVI

The Soil-Adjusted Vegetation Index (SAVI) is a vegetation index that attempts to minimize soil brightness influences using a soil-brightness correction factor. This is often used in arid regions where vegetative cover is low.

In general, most vegetation indices rely on the existence of a "soil line" in red and NIR wavelength space, i.e., there is a principal axis of soil spectral variation extending outward from the origin with increasing brightness. Since most soil spectra fall on or close to the soil line, and since the intercept of such a line is close to the origin, RVI and NDVI values of bare soils (ratios) will be nearly identical for a wide range in soil conditions. A secondary axis of soil variation (the width of a "global" soft line) may be significant in certain cases and may hinder the detection of low amounts of vegetation (Huete, 1988). SAVI formula is given in equation 2.6.

$$SAVI = ((NIR - Red) / (NIR + Red + L)) \times (1 + L) \quad (2.6)$$

where L is the amount of green vegetation cover.

As stated before, NIR and Red refer to the bands associated with those wavelengths. The L value varies depending on the amount of green vegetative cover. Generally, in areas with no green vegetation cover L=1; in areas of moderate green vegetative cover, L=0.5; and in areas with very high vegetation cover, L=0 (which is equivalent to the NDVI method). This index outputs values between -1.0 and 1.0.

2.1.3.7 SR

The Simple Ratio (SR) is basically used for biophysical parameters of the forest region of remotely sensed data. The formula to calculate SR parameter is shown in equation 2.7.

$$SR = NIR / RED \tag{2.7}$$

Bigger numbers indicate high amount of vegetation, smaller numbers show ice, soil, water in map. Atmospheric and topographic effects are reduced with this ratio-based index.

2.1.3.8 EVI

The Enhanced Vegetation Index (EVI) is an 'optimized' index designed to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. EVI formula is given in equation 2.8.

$$EVI = G*(NIR - RED) / (NIR + C1*RED - C2 * BLUE +L) \tag{2.8}$$

where

G= (GAIN FACTOR) =2.5

C1=6 C2 = 7.5 L=1

2.2 Geographic Information Systems

Assessment of geographic information today is mainly performed through Geographic Information Systems. GIS developed through the 1990s, can be described partly as a digital map producer, partly as a complex tool for problem solving, registration, unit of storage and partly as a piece of software. Stand for some point of view, a combination of general information (maps) and specific information (attributes) is GIS. Many other definitions of GIS have been suggested depending on shape, function, dynamic processes and depending upon how it is used. Geographic systems are built upon a data model. A data model is the mechanism used to represent real world objects and processes digitally in the computer system. In this way data models are closely related to the topic of data representation but usually data models are used as a formalization of representations. In a general GIS system, real-world objects are described and represented digitally, allowing for the user to see and analyze the results.

2.2.1 Web GIS

Web mapping is the process of designing, implementing, generating, and delivering maps on the World Wide Web and its products, which is the process of using maps delivered by geographical information systems. Since a web based map is served and consumed, web mapping is more than just web cartography, it is both a service activity and end-user activity. To put it bluntly, it is some type of internet application that makes use of a map. This could be a site that displays the largest geo-tagged images from such as Flickr, a map that shows markers of locations we have travelled to, or an application that tracks invasive plant species and display them. If it contains a map and it does something, we could argue that it is a web map application. The term can be used in pretty broad sense. According to Kraak and Brow (2001), web GIS emphasizes geo-data processing aspects more involved with design aspects such as data acquisition and server software architecture such as data storage and algorithms, than it does the end-user reports themselves. The terms Web GIS and web mapping remain somewhat synonyms. Web GIS uses web maps, and end users who generate web maps are gaining analytical capabilities. The term location-based services refer to web mapping consumer goods and services. Web mapping usually involves a web browser or other user agent capable of client-server interactions.

Advantages of web based mapping can be listed as follows:

- Rich mapping and imagery – road and surface features, orthorectified imagery,
- Scalability – web mapping platforms can easily scale from a few users to millions.
- Cloud computing – base map features flow from cloud servers outside an organization’s infrastructure directly to a user’s browser reducing required server capacity, bandwidth, and IT support.
- Data maintenance – creation and maintenance of base map features is handled by the web service, so additional personnel are not required by the organizations using these services.

- Users – Web mapping application require very little training, and can be tailored for non-GIS users who need to visualize data quickly to make better decisions.

Within the past few years, the popularity of interactive web maps has exploded. In the past, creating interactive maps was reserved for large companies or experts with lots of money. But now, with the advent of free services like Google and Yahoo Maps, online mapping is easily accessible to everyone. Today, with the right tools, anyone can easily create a web map with little or even no knowledge of geography or programming.

Web GIS products are expected to be fast, accurate and easy to use. Since they are online, they are only a few tools that fulfill all these expectations. Windows Azure is used as background environment, which is one of the most popular integrated cloud services—analytics, computing, database, mobile, networking, storage, and many more. There are lots of GIS servers, tools and services which are used for generating web based GIS products. Most important and popular components of Web GIS are listed and explained in the following sections.

2.2.2 ArcGIS

ArcGIS is a desktop mapping and spatial data analysis application produced by Esri It allows to user to create their own maps from scratch starting with geographic data in electronic form and to analyze data that has a locational component.

ArcGIS uses the concept of a Geographic Information System (GIS) to build maps in which each category of spatial feature is a separate layer. The layers are spatially "registered" so when the user overlays them the program can line them up correctly to build a map. There are several types of layers, and the user has many choices regarding how to depict them. The first three listed are called "vector layers" or "feature layers" and contain individual features that the program can distinguish;

- **Point** (e.g., buildings, landmarks). Zero-dimensional.
- **Line**, or arc (e.g., roads and streets, streams, railroads, power lines). One-dimensional.
- **Polygon** (e.g., political entities, census geographies such as tracts). Two-dimensional.

- **Raster images** (e.g., an aerial photograph, scanned topographic map, or an elevation model).

Contrasting with feature-based vector layer, these are images based on an X by Y grid of cells, each of which has a value that represents something like elevation, land use classification, or color value. Data can be associated with the spatial features, and mapped or analyzed. There can be attributes, or tabular data, associated with each feature in a layer. Data tables (e.g., database or spreadsheet files) can be added ("joined") to a layer if there is a field with common values.

The program can also map spatially referenced data files in some spreadsheet and database formats (e.g, if one field contains latitude/longitude coordinates). Tables that contain address data can be "geocoded" to map the locations based on a street layer. Users can open a non-registered raster image and georeference it using the program's functions, or vectorize features from a raster image. (Duke University, 2017)

2.2.2.1 Model Builder

Model builder is a component in ArcGIS Pro which is used to automatize tasks. It is principally appropriate for batch processing. User can generate a model by dragging and dropping objects, tools, etc. and then operating the model in ArcMap. User can hard code particulars like file paths into your model or have your model prompt a user for information to make it more adjustable. User can also save the model and share it with other users.

2.2.2.2 Geoprocessing, Services and Tools in ArcGIS

The principal objectives of geoprocessing are to allow the user to automate GIS tasks and to carry out spatial analysis and modeling. Around all uses of GIS involve the recurrence of work, and the repetition forms the demand for methods to automate, document, and share multi-step actions known as workflows. Geoprocessing supports the automation of workflows by providing a rich set of tools and a contraption to unite a series of tools in a sequence of operations using models and scripts.

The kinds of models to be automated can be ordinary—for example, to wrangle herds of data from one format to another. Or the models can be quite creative, using a sequence of operations to model and analyze complex spatial relationships—for example, calculating optimum paths through a transportation network, predicting the path of wildfire, analyzing and finding patterns in crime locations, predicting which areas are prone to landslides, or predicting flooding effects of a storm event.

Geoprocessing is based on a framework of data transformation. A typical geoprocessing tool performs an operation on an ArcGIS dataset (such as a feature class, raster, or table) and produces a new dataset as the result of the tool. Each geoprocessing tool performs a small yet essential operation on geographic data, such as projecting a dataset from one map projection to another, adding a field to a table, or creating a buffer zone around features. ArcGIS includes hundreds of such geoprocessing tools. General geoprocessing workflow is shown in figure 2.3.

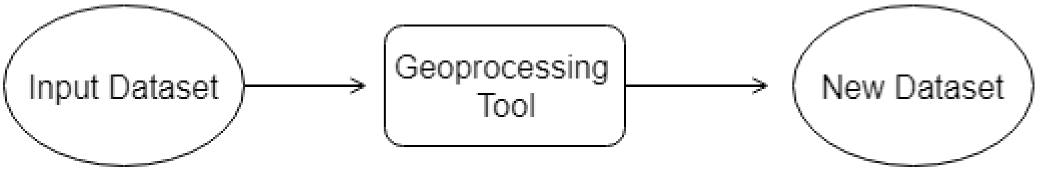

Figure 2.2 Geoprocessing Workflow.

Geoprocessing allows you to chain together sequences of tools, feeding the output of one tool into another. You can use this ability to compose an infinite number of geoprocessing models (tool sequences) that help you automate your work and solve complex problems.

Geoprocessing services are how you expose the powerful analytic capability of ArcGIS to the World Wide Web. Geoprocessing services contain geoprocessing tasks, and a task takes simple data captured in a web application, processes it, and returns meaningful and useful output in the form of features, maps, reports, and files. A task could calculate the probable evacuation area for a hazardous chemical spill, the predicted track and strength of a gathering hurricane, a report of land cover and soils within a user-defined watershed, a parcel map with historical details of ownership, or a permitting application for a septic system. The possibilities for these services are infinite.

A geoprocessing service contains one or more geoprocessing tasks. A geoprocessing task is a geoprocessing tool running on a server, where its execution and outputs are managed by the server. When you share a geoprocessing result as a geoprocessing service, a corresponding geoprocessing task is created from the tool that created the result. Task is a term that web-based APIs (such as JavaScript) use to describe routines that do work on a server and return results.

A useful way to think about services is as four separate activities: designing, authoring, publishing (or sharing), and using (or consuming). The online help about geoprocessing services address the mechanics of authoring, publishing, and using. That is, how to use ArcGIS Desktop and web programming to create and access geoprocessing services and their tasks.

2.2.2.2.1 Raster Calculator tool

The Raster Calculator provides you a powerful tool for performing multiple tasks. You can perform mathematical calculations using operators and functions, set up selection queries, or type in Map Algebra syntax. Inputs can be raster datasets or raster layers, coverages, shapefiles, tables, constants, and numbers.

Map Algebra provides one method to run Spatial Analyst tools. Tools can also be run using dialog boxes or a command line. In the Spatial Analyst functional reference, you can access tool syntax and examples using each of the methods available to run tools.

To access the Raster Calculator, select it from the Spatial Analyst toolbar menu. In the dialog, you can enter Map Algebra into the expression box. An example of the Raster Calculator dialog with a Map Algebra expression already entered is picture to the right.

The Raster Calculator tool is specifically designed to offer the following benefits:

- Implement single-line algebraic expressions.
- Support the use of variables in Map Algebra when in ModelBuilder.
- Apply Spatial Analyst operators on three or more inputs in a single expression.
- Use multiple Spatial Analyst tools in a single expression.

Raster Calculator is designed to execute a single-line algebraic expression using multiple tools and operators using a simple, calculator-like tool interface. When multiple tools or operators are used in one expression, the performance of this equation will generally be faster than executing each of the operators or tools individually.

2.2.2.2.2 Select Data Tool

Select Data tool is in the General toolset of the Data Management toolbox. This section discusses the Select Data tool. Folders, geodatabases, feature datasets, coverages, and group layers are all containers of data. Within each container is one or more feature classes, tables, or sublayers (in the case of group layers). The Select Data tool allows you to peer into these containers and extract one of its members for further processing. When building models, you may need to use the Select data tool to retrieve data from a container to use as input to another tool.

The input to the Select Data tool is referred to as the parents, and its members, or children of the parents, are included in the tool's drop-down list. If the input is a feature dataset, all the feature classes within the feature dataset are included in the drop-down list.

Selecting the child from the parents using the Select Data tool enables you to continue processing your data after performing a task where the output data is a container, such as a feature dataset, and the tool requires a feature class.

2.2.2.2.3 Reclassify Tool

The reclassification tools reclassify or change cell values to alternative values using a assortment of methods. You can reclass one value at a time or groups of values at once using alternative fields; based on a criterion, such as specified intervals (for example, group the values into 10 intervals); or by area (for example, group the values into 10 groups containing the same number of cells). The tools are designed to allow you to easily change many values on an input raster to desired, specified, or alternative values.

All reclassification methods are applied to each cell within a zone. That is, when applying an alternative value to an existing value, all the reclassification methods apply the alternative value to each cell of the original zone. No reclassification method applies alternative values to only a portion of an input zone.

2.2.2.2.4 Weighted Overlay Analysis Tool

Overlay analysis is a group of methodologies applied in optimal site selection or suitability modeling. It is a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated analysis.

Suitability models identify the best or most preferred locations for a specific phenomenon. Types of problems addressed by suitability analysis. Overlay analysis often requires the analysis of many different factors. For instance, choosing the site for a new housing development means assessing such things as land cost, proximity to existing services, slope, and flood frequency. This information exists in different raster with different value scales: dollars, distances, degrees, and so on. You cannot add a raster of land cost (dollars) to a raster of distance to utilities (meters) and obtain a meaningful result.

Additionally, the factors in your analysis may not be equally important. It may be that the cost of land is more important in choosing a site than the distance to utility lines. How much more important is for you to decide.

Even within a single raster, you must prioritize values. Some values in a particular raster may be ideal for your purposes (for example, slopes of 0 to 5 degrees), while others may be good, others bad, and still others unacceptable.

The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multi-criteria problems such as site selection and suitability models. As with all overlay analysis, in weighted overlay analysis, you must define the problem, break the model into sub models, and identify the input layers.

Since the input criteria layers will be in different numbering systems with different ranges, to combine them in a single analysis, each cell for each criterion must be reclassified into a common preference scale such as 1 to 10, with 10 being the most favorable. An assigned preference on the common scale implies the phenomenon' preference for the criterion. The preference values are on a relative scale. That is, a preference of 10 is twice as preferred as a preference of 5.

The preference values not only should be assigned relative to each other within the layer but should have the same meaning between the layers. For example, if a location for one criterion is assigned a preference of 5, it will have the same influence on the phenomenon as a 5 in a second criterion.

For example, in a simple housing suitability model, you may have three input criteria: slope, aspect, and distance to roads. The slopes are reclassed on a 1 to 10 scale with the flatter being less costly: therefore, they are the most favorable and are assigned the higher values. You do the same reclassification process to the 1 to 10 scale for aspect, with the more favorable aspects, in this case the more southerly, being assigned the higher values. Each of the criteria in the weighted overlay analysis may not be equal in importance. You can weigh the important criteria more than the other criteria. The input criteria are multiplied by the weights and then added together. For example, in the housing suitability model, aspect is multiplied by 2 and the three criteria are added together, or represented another way, (2 * aspect) + slope + distance to roads.

The final step of the overlay analysis process is to validate the model to make sure what the model indicates is at a site is actually there. Once the model is validated, a site is selected and the house is built.

3. SPECTR-AGRI-ITU WEB APP

‘Spectr-Agri-ITU’ is a web based, spatial design collaborated application which can produce meaningful data from raw imagery data. This app was generated using ArcGIS desktop environment and its tools such as model builder and weighted overlay analysis geoprocessing tool. ArcGIS PRO provides users designing, implementing and managing spatial data effectively and dynamically with web GIS architecture. Also, users can publish their own map or data on web via online web services.

To start to form the project, ArcGIS PRO is initialized firstly. Home screen of this program appears on screen as shown in Appendix A.1 shows details of project as name, location or geodatabase folder. ArcGIS PRO needs named user for ArcGIS Server user may activate ArcGIS PRO and its extensions such as Spatial Analyst, so signing in with username and password of ArcGIS Server. (Appendix A.2)

New project is created and named after logging in the online system. (Appendix A.3) On the contrary to ArcMap which is the most powerful environment of spatial data management, ArcGIS PRO has different type of interface and abilities especially it works with ArcGIS Online or ArcGIS Portal dynamically, it collaborates with web servers more efficiently therefore, it has been chosen as a working environment of this project.

Initial page appearance of this program is shown below from scratch. (Appendix A.4) ArcGIS topographic map was chosen as the basemap of this project. To perform this, firstly New Map button where stands top left of the screen is clicked and New Basemap was clicked as shown in the Appendix A.5 and Appendix A.6. To add raster data, Add Data button was clicked in Map tab and data was selected in dropdown menu. This raster data added to test the application features. (Appendix A.7 and Appendix A.8)

Sample multispectral raster data belongs to the city of Konya. Eight bands multispectral raster data is for verifying the model.

After adding raster data to the map as shown in Appendix A.9. Extent of map is automatically located to input data location. Main screen's appearance is shown in Appendix A.9 let us see map layers together with overlay. Both of raster data layer and basemap layer have different coordinate system but same datum. Projection and transformation abilities of platform let the users to visualize on the fly. After adding all necessities, tool opened by clicking Modelbuilder button on the Analysis tab on top of the bar.

After opening the empty model from Modelbuilder, Utilities button where is on middle-top of the screen was clicked and select data was selected from the dropdown menu. It is used for selecting relevant data in modelbuilder. User can put the utility model to anywhere in empty model builder schema. Appendix A.10 shows model builder schema and utilities.

In this step of process, we are breaking into pieces multispectral bands to single bands from raster placed onto schema as shown in Appendix A.11. These multispectral bands are ready to use by indexes.

There are wide range of powerful Geoprocessing Tools which are for processing geographic and related data. The large suite of geoprocessing tools can be used to perform spatial analysis or manage GIS data in an automated way.

In addition to the variety of tools, geoprocessing also has a powerful framework that supports manage of the processing environment and provides to build custom tools that can further automate the work. Geoprocessing tools can be use included in ArcGIS as building blocks to create an infinite number of custom tools that automate repetitive tasks or solve complex problems (Appendix A.12).

Appendix A.13 shows that Spatial Analyst Tools are available with the Spatial Analyst extension. Extension provides a broad range of powerful spatial modeling and analysis capabilities. To create, query, map, and analyze cell-based raster data;

- deliver performance integrated raster/vector analysis;
- derive new information from existing data;
- query information across multiple data layers.

Map Algebra allows you to access the Spatial Analyst tools, operators, functions, and classes through algebra to perform geographic analysis. In its most basic form, an output raster is specified to the left of an equal sign (=), and the tools, operators, and their parameters are on the right. (Appendix A.14 and Appendix A.15)

Every single bands as a raster layer are prepared to connect Map Algebra. The Raster Calculator tool executes Map Algebra expressions. When using multiple Boolean (~, &, ^, |) and/or Relational (<, <=, >, >=, ==, !=) operators consecutively in a single expression, using the parentheses is critically important.

3.1 Modelling the vegetation indices

Mainly and simply to tell, vegetation indices are mathematical expressions between raster values which are from different bands or sensors. Raster objects can be used as input and are the primary output of Map Algebra expressions. When calculating a Map Algebra expression that uses operators, the inputs must be either imagery objects or constants.

Imagery outputs from Map Algebra expressions are meant to be temporary, also may be saved by using the save method on the Raster object. Ready to use operators may be used or typing the expression in Raster Calculator expression pane is adequate. Raster calculator pane shown in Appendix A.16. Mathematical expression which are calculated for vegetation indices are entered in map algebra for each index (Appendix A.17 – A.23).

After all calculations of indices are completed, Modelbuilder needs validation. Created vegetation indices validated via run tab in Modelbuilder pane. (Appendix A.24)

Inputs are defined to Algebra expressions for automated catch in model (Appendix A.25). Variables point the analysis which are input or output for function. Bounds created to show relations as shown in Appendix A.26 and Appendix A.27.

Reclassification of vegetation index raster is primary necessity before weighting the raster with common influences. (Appendix A.28)

3.2 Weighted Overlay Analysis

Weighted Overlay tool is in overlay ribbon in Spatial Analyst Toolbox. Tool enables customize influence and weights of raster data. Total influence must be 100% to analyze. (Appendix A.29 - Appendix A.30)

3.3 Publishing model to web via geo-processing services

Generated model in Modelbuilder is a ready to execute tool which is in xml format and usable in desktop software.

ArcGIS Pro is dynamically integrated with Web GIS environment. Using web geo-processing service from ArcGIS Pro, ArcGIS Enterprise which includes

- GIS Server,
- Data Store to configure storage for data used by the hosted services,
- Web Adaptor to run in existing website and forwards requests to ArcGIS Server machines,
- Portal for application interface,
- Share as a web tool, providing model to be executed in web GIS environment.

  URL created for ‘Spectr-Agri-ITU’ web app as follows: https://itu-spectragri.maps.arcgis.com/apps/webappviewer/index.html?id=71e9093e12fb4c59a000f58b43cc160d

Entering the url in any web browser, let users execute the analysis on World Wide Web and export the output image as showed in Appendix A.32 and Appendix A.33.

4. RESULT & DISCUSSIONS AND FUTURE WORK SUGGESTIONS

Mapping is the most efficient way to visualize spatial information and helps us informing and having a better understanding. Location based, spatially analyzed geographic objects, while the shape and color of signs and symbols representing the objects, also inform about their characteristics. It reveals spatial relations and patterns, and offer the user insights and overview of the distribution particular phenomena.

The advantage of this system is that each sections can be produced by different functions and any component of the structure can be replaced with other variations and vice versa. Web-GIS is a fast developing and changing field indeed, the technology has gone through many iterations. The Web is the ideal platform for GIS. Web-GIS allows professionals, organizations, and the public share and collaborate. Implementing GIS eminently more accessible to a wide range of users all around the world.

Additionally Open-Source Web-GIS systems have reached a stage of maturity, sophistication, robustness and stability, usability and user friendliness. The Open-Source Web-GIS community is also actively embracing Open Geospatial Consortium (OGC) standards. Web services enables the creation of Web maps that have layers coming from multiple different remote servers/sources. Users can switch to browse the e-map or the satellite images and manipulate the map functions, like pan, zoom in/out, zoom to full extent, etc. Users can also utilize query tool to query specific information of locations. Therefore, the map display content can be greatly enriched and users can understand the process of GIS data collecting, managing and displaying by manipulation.

Remote sensing is easy to access present day than past. Collecting data via our widgets is reachable even for personal use. Along with drones and UAVs has cameras for air photographing, filters which are compatible with cameras enables us to access spectral imagery. This way is more efficient in wide range of manners. The acquisition of imagery for the same location is 16 days for Landsat 8 satellite which is a good rate. Researchers may fly drones and UAVs anytime incidents happen or specific time as flowering, harvesting, etc. which is important for vegetation.

As working and studying with agricultural scientists, GIS analysts and web designers, bringing these multi-disciplinary manners together has critical importance to sharing and spreading ideas for future.

This thesis study concentrates on the topic of GIS and remote sensing using a multispectral imaging system for vegetative research and its use mainly in agricultural applications. In this context a Web-GIS application, namely Spectr-Agri-ITU, has been developed using some indices mentioned before. This app could be a very useful interface for all concerning vegetation and agriculture.

In conclusion, this thesis showed the basis for creating a Web-GIS application with remote sensing and spatial analyzes feed, in order to show the fields to use of executed analyzes and functions. Researchers needs will give form to raw imagery through the spectral transformation.

This multi-disciplinary research gives insights of healthiness/sickness, abundance/lack of minerals, water stress or else about greenness and vegetation.

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