HYDROLOGY AND WATER RESOURCES REMOTE SENSING IN SOIL AND WATER RESOURCE MANAGEMENT

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ABSTRACT

Satellite data and images with different place resolving power have been utilized and employed in the development planning and decision-making process in many developing countries because of lack aerial pictures. The development planning in the developing countries are composed of 4 levels:

- Regional planning
- Perspective planning
- Development planning
- Project planning

Taking into consideration of different levels of development planning, the satellite images with different place resolving power (Low, Average, High) has various applications. The applications of remote sensing in soil and water resources can be classified in three main groups:

- Surveying sewage and irrigation process in wider regions.
- Identifying different lands in the local scale, land salinity and determination of amount of product harvesting.
- Preparing farming land maps and solving problems related to legal aspects and or land ownership.

In this respect, the sensors or satellite producing suitable images for the management of sewage and irrigation networks are classified in different groups. Some of these parameters which can be extracted from the satellite are:
Topography data, Land use, Soil salinity, Soil moisture, Formation of waterlogged, Water balance, Growth of agricultural products, … each of which has specific precision in using the satellite data.

Key Words: Remote sensing, Soil & Water Resource, Management, Satellite Data

INTRODUCTION

The use of satellite images for the development of natural resources started for the first time in 1972 with the launch of the American satellite called Earth Resources Technology Satellite (ERTS). Later the name of this satellite was changed to Landsat-1. In the next years, other countries launched other satellites with better spectrum, time and place resolution power. The most important factors caused implementation of the satellite technology in the development of the natural development was lack of aerial pictures in many developing countries as well as ever-increasing use of satellite information in decision-making process. From the various studies conducted by means of satellite date with high place resolution power, it can be concluded that a better understanding and interpretation of the land coverage and application can be provided by means of the satellite images with very high place resolution power.

TYPE OF PLANNING

The planning system in the developing counties is of comprehensive one and consists of a set of four interrelated levels of planning which are;

- **Regional Planning:** This planning is done at large scale or level, and its planning ranges from 1: 250000 to 1: 1000,000. This type of planning is long – term and covers one or several provinces or states. Such planning is equivalent to regional economic development.

- **Perspective planning*:*** This type of planning is regional, and its scale ranges from 1: 50000 to 1: 250000. This planning, too, is long-term. The objective of this planning is to provide one structure or frame for guiding the development plan.

- **Development Planning:** is at average level or scale and has the range of 1: 25000 to 1: 50000. Such plans are usually for 5 years.

- **Project Planning:** This planning is done at a small level and / or scale (in a village or small basins), and the scale of such plans is from 1: 1000 to 1: 5000.

The different types of the above-mentioned planning face different problems in the developing countries. These problems are caused by rapid growth of population and limitation of resources and have led to imbalance at social-economic development levels. Such problems appear in the form of low level of incomes, small landownership, and week social services weakness of infrastructures, low level of literacy and sanitation of destruction of environment.

Irrespective the social-economic problems, the developing countries encounter other problems as well. These include technological backwardness and lack of technical infrastructures to support the comprehensive planning. There are following problems in connection with place economic development planning;

- Non existence of the latest topographic maps as well as Cadastre maps.
- Non existence of technological structures
- Existence of security issues in connection with the use of topographical maps and that of satellites with high place resolution power.

USING SATELLITE IMAGES FOR DEVELOPMENT PLANNING

Taking into consideration the different levels of development planning stated above, planners analyze the maps relating to the region(s) in question in different scales. In macro level planning, the map must have information at the regional level such as natural relief's, agricultural lands, jungle regions, water basins, land application, communication networks , situations and place distribution of habitants in the scale of 1 : 250000 to 1 : 1000,000. But in the local planning, the maps consists of comprehensive information concerning the culture pattern jungle species, infrastructures (resources of water, energy and communication networks) services (therapeutic, hygienic and educational services) etc., in the scales 1 : 1000 to 1 : 5000. These maps must be summarized at different levels. Although a small polygon in the regional scale represents extensive regions, this polygon, in the local scale may be divided to different classes such as residential, trade, industrial and recreational units, etc. Studies show that the satellite images with low place resolution power while working at a regional scale are better than the images with high place resolution power whereas at the local scale the satellite images with very high place resolution power have a better application. To survey the agricultural lands, prepare geological maps, exploit underground water, the satellite images with low place resolution power provide a systematic and / or multilateral view of the area under investigation. At the local levels, the satellite images with more details (satellite images with high place resolution) are useful. These data are used to identify the rate of changes in the agricultural products, water resources, jungle regions, applications in the urban lands and infrastructures. Different satellite meters cover an extensive range of place resolution power.

PROBLEMS RELATING TO PLACE RESOLUTION POWER

To prepare different maps in connection with any development planning, the temporal, radiometric, spectral and place resolution power with which the meters gather data of remote sensing are of great importance. For local planning, high resolution power is suitable, whereas low resolution power is suitable for regional and national planning. The high place resolution power provides the possibility to observe smaller reliefs and causes these to be drawn on the maps. The choice of special spectral bands the possibility to identify different types of coverings and land applications, the highness of radiometric resolution power causes the identification of the smallest changes in the reliefs and the highness of the temporal resolution power cause the identification of the smallest change in any relief in the course of time.

Therefore, in different development projects this resolution power will vary. Thus the highness of the place resolution power is relative so it will vary in different applications like environmental planning, water resource planning, management of natural catastrophes, rural and urban development, etc. For complex, if we want to plan water resources nationally, the resolution power 150 – 250 will be suitable, but for the management and planning of small basins (local levels) the satellite images with the place resolution power equal to 1 – 10 m. will be appropriate. The Ikonos Satellite receives the satellite images with the place resolution power of 1 – 4 meters. These images are suitable for local planning or small water basins.

Table 1: Application of Satellite Images for Different Levels of Development Planning

	High Resolution Power	Intermediate Resolution Power	Low Resolution Power
	100 – 1000 m.	50 – 20 m.	1 – 5 m.
Planning Level	Macro (Regional / Perspective)	Regional	Small Water Basins
Map Scale	1: 50000 – 1: 1000,000	1: 25000 – 1: 50000	1: 1000 – 1: 5000
Application	Possible Application		Expected Application
Water Resources	- Extraction & Determination Of Water Basins & Prioritization of water Basins for Development - Extraction of Ice & Snow Cover Maps	- Perspective of Underground water Resources - Prioritization of water Basins - Estimation of Snow Melting & water Runoff	- Planning & Management of Small Water Basins - Measurement & Monitoring of Development Projects - Locating of Water Installation
Planning of Infrastructures	- Planning of Infrastructures at Macro scale	- Analyses related to Appropriateness of Lands for Development - Preparation of Infrastructure Maps	- Place Analysis of Projects Such as Dams Irrigation & Drainage Network, Power Plants - Other water Installations
Planning of Land Application	- Preparation of Land Application Maps at Level 1 - Preparation of Water Basin Maps at Level 1	- Preparation of Land Application at levels 2 & 3 - Analysis of changes in Land application - Preparation of water Basin Maps At level 2 & 3	- Preparation of Land Maps
Determination of Cultivated Area	- Lands on which mono-cultural Pattern is Common	- Lands on which multi-cultural pattern is common	- lands on which multi - cultural Pattern is common and lands are very small

TECHNOLOGICAL CONVERGENCE – TODAY'S NEED

With emergence of modern technology, gathering data by means of GPS as well as the analytic instruments in geographical information systems has provided accessibility to the place data. The amount of the effectiveness of the place technology like GIS, GPS photogrametry and remote sensing in the process of planning and decision-making depends on this fact that these technologies must be provided to the final users so that they can employ them in solution. Systematic use of this technology will cause most of the problems related to planning and managerial decision-making to be sorted out.

PRESENT STATUS OF REMOTE SENSING TECHNOLOGY

Satellite Systems

The applications of remote-sensing in irrigation and drainage can be classified to three groups;

A. Measuring irrigation and drainage processes in more extensive regions.
B. Identification of different lands at local scale, land salinity and determination of product harvest amount.
C. Preparation of agricultural land maps and solving the problems related to legal aspects and / or land ownership.

Application of group A needs gathering repetitive images; therefore, the images needed in this group must have resolution power (250 – 1100m.) with one day of repetition. In the group B, too, multi – spectral images are needed. The images needed in this group must have a place resolution power of 15 – 30 meters. In group C, too, we deal with very high place resolution power (1 – 6 m.). These images are suitable for realization of small reliefs on the ground. Every year limited images of this group are needed. One of the meters mounted on satellites in spectrometer which measures the electromagnetic radiations in the narrow and limited parts of the electromagnetic spectrum. Some of spectrometers only have some spectral band (for example, Ikonos has four narrow spectral bands and one wide band), whereas another group of the spectrometers have more bands and measures wider parts of the electromagnetic spectrum (for example, Modis meter has 36 narrow spectral bands). The visible bands are between 0.4 – 0.7 micrometers. The blue band has the lowest wavelength (0.43 – 0.48 micron) and the green and red band have (0.51 – 0.56 micro) and (0.62 – 0.76 micron) respectively. The close infrared band varies between 0.7 – 1.5 microns and the thermal infrared is between 8 – 15 microns. The price of the images in group C is very high compared to the groups A and B. In most cases, the images of the group A are available free of charge. In the U.S.A., the price of the images in the group B is very low. Many agencies have already created digital archives from the satellite data to reduce the time between receiving and delivering data to customers. The data can be selected and ordered by internet, and sometime the data can be saved directly. This causes reduction in the time needed to receive and process the data.

Table 2: Meters or Satellites that Produce Suitable images for the Management of Irrigation and Drainage Network

Type of Application	Meter or Satellite	Group
- Determination of Land limits - Preparation of Maps for Irrigation & Drainage Networks - Extraction of Cartographic Information - Identification of Waterlogged in Small Scale - Identification of land Salinity in Small Scale	Ikons, SPIN, IRS IRS (Pan), SPOT (Pan)	A
- Application of Lands - Irrigated Regions - Identification of Product Type - Determination of Soil Salinity Rate - Ponding - Index of leaf Surface - Potential Transpiration & Evaporation	Landsat, SPOT, IRS, ASTER, CBERS	B
- Rate of Growth in Agricultural Products - Rate of Product Harvest - Rate of Product Transpiration & Evaporation - Determination of Soil Humidity Rate in Root Region	Landsat, ASTER, CBERS	B
- Floodwater - Determination of Humidity Rate in Surface Soil - Determination of Evenness Rate of Ground Surface	Radarsat	B
- Determination of Rate Agricultural Product Growth - Determination of Rate of Agricultural Harvest - Determination of Rate of Product Transpiration & Evaporation - Floodwaters - Potential Transpiration & Evaporation	NOAA, AVHRR, TERRA, MODIS	C
- Precipitation	TRMM, METEOSAT	C

DRAINAGE PARAMETERS

Some of the drainage parameters that can be extracted from the satellite data are presented in the following table

Table 3

Type of Parameter	Name of Group
Evaluation of Soil Salinity	B
Soil Salinity As one of Natural Calamities	B
Management of Water for Agricultural Consumptions	A, B
Evaluation of Drainage Systems in Connection with Soil Salinity	B, C
Percolation & Drainage System	A, B
Evaluation of Operations of Drainage & Irrigation System	A, B
Creation of Soil & Water Resource Information Systems	C
Index Leaf Surface & Soil Humidity	B
Preparation of Soil Salinity Map	B

LAND APPLICATION AND TOPOGRAPHIC INFORMATION

To prepare maps for land application and discovery of changes made in agricultural lands and irrigation regions, the images of high place resolution power are required. The images taken by Ikonos and SPIN are the place resolution power 1 – 4 meters. Therefore, these images can be used in legal problems and determination of land ownership. Formation of waterlogged and salinity of soils occur in the places where the type of irrigation systems is in the form of water logging. The panchromatic images taken by the satellites Landsat (15m.), SPOT (10m) and IRS (6m) can be used to extract canals and prepare the map for water leaking effects in the adjacent grounds.

The determination of the area under cultivation is the basic information required for the optimal allocation of water as well as designing irrigation and drainage networks. The information related to water lands can be utilized for the economy of water resources. The multi-spectral data taken from Landsat, IRS and SPOT can be used for the classification of the agricultural lands. The precision of the maps resulting form these resources is about 85 %. Through the data extracted from these satellites, the fruit trees can be distinguished because the spectral behavior of the cover between the trees affects the manner of the spectral reflection, but the trees are of different sizes and ages and their diagnosis is difficult.

SOIL SALINITY

The statistics pertaining to the area of the soils affected by salinity and also the beginning time of soil salinity is rarely available and is often uncertain. The phenomenon of soil salinity occurs both naturally and as a result of the human interventions in the water cycle though irrigation. The salts are displaced through the displacement of soil humidity. Therefore, the depth – time behavior of the soil is dynamic. In order to determine the salinity of the soil we require the longer temporal series measurements. Although most of the remote sensing studies in connection with the soil salinity have been done by means of the data taken from the Landsat and SPOT satellites, at present the attempts are made locally to use the data from the satellites of very high resolution power. The phenomenon of the soil salinity is one of the natural calamities not a peripheral variable.

The dominant ions existing in soil determine the type of the salt as well as the color of soil. The change in the soil color reflects the process of the soil salinity and affects the electromagnetic spectrum as well. The neutralization of soil causes the whiteness of soil and its alkalinity cause soil to become black. The existence of sodium makes soil harder. The alkaline soils compared to sodium soils absorb more electromagnetic radiation. Carbonates in the red band can be diagnosed easily whereas the chloride anions can be distinguished through the green and blue bands. If the soil salinity takes place in root region the soil salinity can not be determined quantitatively through the green and bleu bands. To identify the salt domes on the ground the spectral reflections in the red and infrared bands can be used.

Drawing upon the red and infrared bands the soil salinity can be classified as follows;

- Regions without soil salinity
- 25 % of the region's soil is affected by salinity.
- 25 – 50 % of the region's soil is affected by salinity.
- More than 50 % of the region's soil is affected by salinity.

The soil salinity is expressed in terms of remained sodium carbonate (RSC) electric conduction (EC) and sodium absorption rate (SAR) while framers define this phenomenon differently. There is a reasonable correlation value (60%) between electric conductivity in the depth of 0 – 30 cm. and 30 – 60 cm. on one hand and the infrared, red and green spectral bands on the other hand in the vast water regions affected by non –sodium salinity and having single cultivation (wheat and corn). Several regression models have been developed between the electric conduction and the bands 2 (green), 3 (red), and 4 (infrared) of TM meter. With regard to the type of the product (wheat, cotton and corn) and the spectral bands, there exist the correlation coefficients 0. 64 % - 0.86 %

At present they can not be used to estimate the depth of underground tables unless this estimation relates to the depth of a few centimeters down the surface. The amount of product is affected by the soil salinity rate in special environments and circumstances.

SOIL HUMIDITY AND WATERLOGGED FORMATION

In the regions where the water gathers on the surface of the ground and / or near the ground surface, the amount of reflection comes down in all electromagnetic spectrum. As a result of increase in the wavelength, the amount of reflection comes down in the wet land which causes the extraction and recognition of the wet lands to be done easily.

The amount of the soil humidity is determined in two ways;

- Determination of the amount of the soil surface humidity by means of radar ray. The radar ray passes through the plant covering and scatters after having penetrated some centimeters down the soil depth.
- Determination of the amount of soil humidity in the root regions. The amount of the humidity in the root regions has a reverse relationship with the surface energy balance which indicates the amount of humidity in the root region.

The unevenness of the soil surface as well as the plant covering affects the signals of operative radar (SAR). Optical sensing is sensitive to the amount of the plant covering. Whereas the microwave remote sensing is sensitive to the amount of the soil salinity and humidity. By combing the optical and radar images, a better estimation of the amount of humidity existing in the region of the plant covering can be provided. The precision of the resultant estimations can be raised with the model of two-layer retro dispersion. For instance, the classes of the soil (humidity which can be extracted are in the form of 1) dry lands 2) lands with low humidity 3) lands with average humidity and 4) Lands with high humidity.

But there are no radar data with high place resolution power. Consequently they are not suitable for the studies relating to the drainage networks presently, but the prospective meters will make this possible. The classes with the humidity of 5 % distances can be extracted exactly. A relationship must be established between the variable of soil type and amount pf porosity.

WATER BALANCE

By using the Surface Energy Balance Algorithm for Land (SEBAL), the real transpiration and evaporation can be calculated with an acceptable accuracy. By combing the real transpiration and evaporation with the changes in the soil humidity in the root region and the data relating to the ombrometry stations together with the data related to the water supply for different consumption, the drainage flow can be calculated as the remainder of the water balance. This drainage category includes those of percolation. But if the amount of water in one region is more than the tank volume, this water must be evacuated. The calculation of the amount of the drainage volume is very important for designing the underground drainage and irrigation networks. In the case that the surplus water is not evacuated through an underground drainage system, the level of the underground water tables will increase and cause the formation of water logging in the end.

GROWTH OF AGRICULTURAL PRODUCTS

Different models have been developed for the evaluation of the growth of the agricultural products. These models have been achieved by establishing relationships between the spectral indexes of the plant covering with that of the leaf surface, but these relationships must be calibrated with grounds yields in different years. The amount of the fruit harvest (banana, grape), Cereals (wheat, rice) and trade products (tea, cotton) has been predicated with the accuracy of 85 %.

The basic problem in using the satellite data to determine the amount of evaporation, transpiration and growth of the agricultural products, is to use different series of the satellite images with high resolution power to recognize the agricultural products, the images taken by the Landsat ate suitable. Owing to the 16 – day imaging cycles of the Landsat and also the existence of cloud in the images, the only use of the images from the Landsat is not accountable for the above applications. Thus, to prepare more temporal series the satellite images with low resolution power must be used (1000m.).

The limitation of the data form NOAA and MODIS is that these data can not be used to distinguish the agricultural pieces. Using the satellite data combination techniques is a suitable way to combine the different satellite data.

Table 4: Accuracy of Drainage Parameters Estimated By Means of Satellite Data

Parameter	Resultant Accuracy (Percent)
Topographic Specifications	81
Application of Lands	84
Amount of Land Humidity (Drought Index)	78
Soil Humidity (Surface Soil)	70
Soil Humidity (Root Region)	64
Water loggings	87
Surface Drainage	78
Amount of Surface Salinity	77
Soil Salinity	63
Irrigated Regions	85
Identification of Product Type	78
Biomass Growth	79
Amount of Product Harvest	72
Determination of Water Cost	93
Soil Corrosion	68
Average	78

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