

# ON THE ASSESSMENT OF SATELLITE AND CONVENTIONAL CROP YIELD ESTIMATION METHODS

Sanaz Shafian-Student of Remote sensing-K.N.T.University

[Sanaz\\_sh\\_rs@yahoo.com](mailto:Sanaz_sh_rs@yahoo.com)

Dr.M Mobasheri-Professor assistant of K.N.T.University

[mobasheri@kntu.ac.ir](mailto:mobasheri@kntu.ac.ir)

Dr.M Valadzouj-Professor associate of K.N.T.University

[valadzouj@kntu.ac.ir](mailto:valadzouj@kntu.ac.ir)

## Abstract

Because of the population increment there is a growing need for micro-level planning and particularly the demand for crop insurance which increases the need for field level yield statistics. Therefore from economic point of view, accurate and fast crop yield estimation is very important in national and regional scale.

There are two methods for yield estimation: Conventional and remote sensing.

Conventional methods are often complicated, costly, time consuming and they cannot be run in large scales. Therefore it is necessary to use cheaper/faster methods for crop yield estimation.

Remote sensing data has the potential and the capacity to provide spatial information at global scale; of features and phenomena on earth on an almost real-time basis.

They have the potential not only in identifying crop classes but also of estimating crop yield.

In this paper first, conventional methods and their disadvantages are reviewed. Then crop yield estimation methods based on remote sensing data, were compared to each other and their advantages and disadvantages are discussed.

*Keywords:* Crop yield, Conventional methods, Remote sensing methods

## Introduction:

Crop yield estimation is very important in national and regional scale (Anup 2005).

Because of the population increment there is a growing need for micro-level planning and particularly the demand for crop insurance (Anup 2005), which increases the need for field level yield statistics.

Also crop yield estimation has an important role on economical development (Hayest and Decker, 1996). These predictions may warn the decision makers about possibility of reduction in the annual yields and therefore allow timely import and export decision.

In many countries the crop yield estimations are based on conventional techniques of in situ data collection for crop and estimation of yield based on the field reports (Reynolds *et al.*2000). These methods are costly, time consuming and are subject to large errors due to incomplete ground observations, leading to poor assessment of yield and crop. Finally in most countries the field collected data become available too late for appropriate actions to be taken to avert food shortage.

Objective, standardized and possibly determination of cheaper/faster methods that can be used for crop growth monitoring and early crop yield estimation in each country are imperative.

Remote sensing data has the potential and capacity to provide spatial information at global scale; of features and phenomena on earth on an almost real-time basis. They have the potential not only in identifying crop classes but also of estimating crop yield.

Most studies have shown a high correlation between vegetation spectral index extracted from satellite images and the green biomass and yield. Therefore, combining vegetation spectral index and the green biomass and yield can be used to estimate yield before harvesting (Groten, 1993).

Agricultural production is a function of complex environmental factors such as solar radiation, water consumption, soil and fertilizer etc. Objective is a crop yield estimation method that can estimate crop yield as a function of these factors by minimum time and cost and maximum accuracy.

## **2. Methodologies**

There are many conventional methods to estimate crop yield. These methods are mostly based on field reports. Two of these conventional methods to estimate crop yield will be introduced here: *Empirical-statistical models* and *Crop growth models* (Jorgensen, 1994).

In a confined region, empirical -statistical models have been studied for many years and effective factor on crop yield are found. Then the crop yield is related to effective parameter through an empirical equation out of which the coefficient of each factor is found. Using these coefficients, one may estimate the crop yield for any other similar region. In most cases, effective factors were environmental.

Crop growth models estimate crop yield as a function of complex interaction of different physiological processes with the environment. These models estimate biomass production potential using daily crop growth simulator. Execution of these methods has difficulties such as: requiring too many ground factors, accurate data and expensive field campaigns.

As a whole, conventional methods have the following disadvantages:

- 1-They cannot be applied to every field
- 2-They are costly and time consuming
- 3-They are not real time applicable

Nowadays in most countries the precision farming program is in their agendas.

Therefore we need to apply methods that can reduce these disadvantages.

The Remote sensing methods are good alternative for this purpose (X.Mo et al, 2004).

Crop yield estimation methods using both satellite images and ground observations were started from 1970. In those days the use of these methods was not usual because satellite images were too expensive while their spatial resolution was low.

From year 1990, the low resolution problem was solved and high spatial and spectral resolution images were produced. Now, in most countries these images are being used because there is a big archive available.

Now we have images that are produced by reflected and scattered electromagnetic wave by which images of different vegetation indices are calculated. These indices are commonly used in real time evaluation of vegetation health and productivity because green mass and content of water, protein...can absorb and/or reflect different parts of electromagnetic spectrum (Anup, 2005).

These methods are divided into 3 categories: 1-Remote sensing methods based on Empirical -statistical models.2- Remote sensing methods based on water consuming balance model.3- Remote sensing methods based on biomass estimation models.

The latter based on biomass estimation methods are divided to two groups: crop growth models (MASS, 1988) and Monteith model (Monteith, 1972)

### 2.1. Remote sensing methods based on Empirical -statistical models

These methods are based on conventional methods, but here spectral indices are calculated from satellite images and not from ground measurement.

### 2.2. Remote sensing methods based on water consuming balance model

These methods estimate crop yield as a function of evaporation fraction during crop growth stages and use water consuming balance model to estimate evaporation fraction. At first the whole growth period is divided into a ten day set and then evaporation fraction is calculated in these sets. If the growth period is divided into a 30 day set, some changes in crop water will be ignored. Also if the model runs in a daily format; it will be costly and time consuming.

#### 2.3.1. Crop growth model

Crop growth models focus on complex interaction of different physiological processes with the environment. In fact these models describe growth stages. There are many ways to combine crop growth models and spectral observation from satellite data were initially described by MASS (1988) and their classification was revisited by Delecolle (1992). Three methods of data integration have been identified:

1-Direct use of a driving variable estimated from remote sensing information in the model;

2-The updating of state variable of the model (for example LAI) derived from remote sensing data;

3-The calibration of model variables by using satellite images (assimilation method)

The general strategy of the model/observations coupling consists of driving variables or parameters which directly occur in the modeling procedure from radiometric observations.

The direct use of remote sensing data to derive a variable assumes that remote sensing data are available at an adequate time step (from daily to weekly). Due to cloud contamination and intrinsic properties of sensors, this is a rare case. Therefore other approaches should be used.

Gaps between dates must therefore be filled by some interpolation procedure.

Substitution of a simulated data value by an observed one (actually derived from the observed reflectance) suggests that the simulation of data is flawed, and therefore the biophysical processes are not well described by the model. But a good description of those processes is required to obtain a consistent estimation of variables such as crop Biomass, which can not be monitored directly by remote sensing.

Assimilation method consists of minimizing the difference between a derived state variable radiometric signal and it's simulated. Difference between satellite observed and simulated value is minimized model parameter calibration.

#### 2.3.2. Monteith model

A simple and useful paradigm for modeling crop yield with remote sensing is derived from Monteith (1972). This model uses Biomass to estimate crop yield.

$$\text{Biomass} = \text{APAR} * \epsilon \quad (1)$$

$$\text{Crop yield} = \text{APAR} * \epsilon * \text{HI} \quad (2)$$

Where:

$\epsilon$ :

the light-use efficiency in units of g biomass MJ-1

HI: harvest index

APAR: absorbed photo synthetically active radiation

Variability in  $\epsilon$  can result from a variety of nutrient, water. Numerous studies have demonstrated that if there is no water shortage, and the temperature is optimal,  $\epsilon$  is a relatively constant property of plants.

In some calculation the effect of temperature and soil moisture is considered for boosting the accuracy.

Like  $\epsilon$ , HI is relatively constant. Values of this factor are experimentally determined and described in the international literature. It can be calculated from crop information in the last years.

Variability in  $\epsilon$  and HI can result from a variety of nutrient, water, and temperature stresses (Russell et al., 1989).

APAR is a fraction of PAR<sup>1</sup> that is absorbed by canopy. Richards and Townley - Smith (1987) indicated that the proportion of water used after synthesis affects the harvest index.

### 3. Result and discussion

In this paper crop yield estimation methods were discussed. Conventional methods found to be based on the field data. These methods were time consuming and could not be considered over field. Therefore were prone to large errors due to incomplete ground observations, leading to poor crop yield assessment and crop area estimations (Reynolds et al.2000).

Remote sensing methods removed above mentioned disadvantages simultaneously (X.Mo et al, 2004).

Remote sensing methods based on Empirical -statistical models should be calibrated in other regions because the factor weights were different in each region and those could not be run in large scale also ignored the effect of other factors.

Remote sensing methods based on water consuming balance model could be run in large scale but they ignored the effect of many parameters such as: solar radiation, photosynthesis magnitude...

Crop growth models were complete models that considered the most effective parameters. They could be run in large scale but entered to much agriculture science details and had lots of parameters. Therefore their executions were costly and time consuming.

Monteith model considered the effect of solar radiation and photosynthesis by APAR calculation and also the effect of temperature and soil moisture on crop yield. This model had few parameters that could be calculated from satellite images .The model could be run in large scale. Therefore, Monteith model estimated crop yield by maximum accuracy compare to the other satellite based methods.

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