Research Application Summary

Estimation of teff yield using remote sensing and GIS techniques in Tigray region, Northern Ethiopia

Yohannes Zenebe, G.
Mekelle University, Department of Geo-information and Earth Observation Science for Natural Resources Management
Corresponding author: Zgebreyohans@yahoo.com

Abstract

Teff is one of the most important cereal crops in Ethiopia where about 66% of the population relies on it for food. . It is a gluten-free food crop which has attracted much interest in the international market. Forecasting Teff crop yield well before harvest is crucial in Tigray as the region is characterised by climatic uncertainties. Given that drought is a common occurrence in the region, timely and quantitative information on expected Teff crop yield will improve the area food production and in turn improve the country's food security. A timely assessment of emergency situation will also allow the regional government to intervene with specific measures that support local farmers. Remote sensing images are capable of identifying crop health as well as predicting its yield. In this study, Normalised Difference Vegetation Index (NDVI) calculated from remote sensing images will be used to monitor crop growth and relate to crop yield. The satellite data will be validated using ground truth in farmer's field.

Key words: Landsat, NDVI, Teff yield

Résumé

Le Teff est l'une des cultures céréalières les plus importantes en Ethiopie, où environ 66% de la population s'en servent comme nourriture. Il est une culture vivrière sans gluten qui a suscité beaucoup d'intérêt sur le marché international. La prévision du rendement de culture du Teff bien avant la récolte est cruciale dans le Tigray comme la région est caractérisée par des incertitudes climatiques. Étant donné que la sécheresse est un phénomène fréquent dans la région, des renseignements opportuns et quantitatifs sur le rendement attendu de la culture de Teff permettront d'améliorer la production alimentaire de la région et à son tour améliorer la sécurité alimentaire du pays. Une évaluation rapide de la situation d'urgence permettra également au gouvernement régional d'intervenir avec des mesures spécifiques qui prennent en charge les agriculteurs locaux. Les images de télédétection sont capables d'identifier la santé de la culture ainsi que prédire son rendement. Dans

cette étude, l'indice normalisé de végétation de différence (NDVI) calculé à partir des images de télédétection sera utilisé pour surveiller la croissance de la culture et de l'associer au rendement de la culture. Les données satellitaires seront validées à l'aide de la vérité sur terrain dans le domaine des fermiers.

Mots-clés: Landsat, NDVI, rendement du Teff

Background

Agriculture is the backbone of the Ethiopian economy, contributing about 57 % of the country's the Gross National Product (GNP), a livelihood to about 85 % of the population and 90% of its export earnings (FDRE, 1997; UNDP, 2002). For a primarily agriculture based country like Ethiopia, reliable, accurate and timely information on types of crops grown and their acreages, crop yield and crop growth conditions are vital components for planning efficient management of resources. This involves formulating and implementing appropriate prices of agricultural commodities, strengthening country's food security and distribution system and import/export policies of these commodities from time to time. Teff (*Eragrostis teff*) is one of the most important cereal crops in Ethiopia, where it covers more than half of the area under cereals (Habtegebrial *et al*., 2007). Furthermore the demand for teff is creasing so that more land is continually opened for its cultivation. (Hailu and Seyfu, 2000). In Ethiopia, 66% of the population relies on teff for nutrient supply. Its production is therefore critical for national food security. It is used in many forms; for example its flour is fermented and made into *Injera*, a major food staple that provides approximately two-thirds of the diet in Ethiopia. It is also eaten as porridge and used as an ingredient of home brewed alcoholic drinks with high protein, mineral and vitamin content. It is a gluten-free food crop that has attracted much interest in the international market (Spaenij-Dekking *et al*., 2005). The crop has other uses elsewhere. For example, in the United States teff grain is used as a health food, while in South Africa, Europe, Yemen, India it is used fodder.

Given that teff is a staple food crop in the region, its production is critical for the region and national food security. So proper forecasting teff crop yield before harvest will improve the area food production and in turn improve the country's food security. Therefore this research seeks to improve crop yield forecasting methods in Tigray Region. The specific objectives are:

(1) To collect data of past climate and satellite data and develops suitable model for assessing teff crop performance in relation to scenarios of climate change and variability.
(2) produce crop yield forecasting model based on Landsat spectral images (NDVI) so as to produce quantitative yield estimates for teff crop production in the region
(3) to establish the relationship between NDVI and field level teff crop yield.
(4) to assess the accuracy of the teff yield estimation model.

Literature Summary

Crop yield estimation in many countries is based ground-based field data collection. This approach is subjective, costly, time-consuming and prone to large errors due to incomplete ground observation, leading to poor crop yield assessment and crop area estimations (Reynolds *et al*., 2000). In most countries, field based data become available too late for appropriate actions to be taken to avert food shortage (Nuarsa *et al*., 2005).

Satellite remote sensing has been widely applied and is recognised as a powerful and effective tool for estimating crop yields (Bouvet *et al*., 2009; Pan *et al*., 2010; Niel *et al*., 2003; Nuarsa *et al*., 2011). An important goal of agricultural remote sensing research is to spectrally estimate crop variables related to crop conditions, which can subsequently be entered into crop simulation and yield models (Ahlrichs and Bauer, 1983). The main advantage of using remotely sensed information is that it provides a quantification of the actual state of crop for large areas using less labour and materials compared to *in situ* sampling. While crop models provide a continuous estimate of growth over time, remote sensing provides a multispectral assessment of instantaneous crop condition with in a given area (Delecolle *et al*., 1992).

Use of satellite spectral data for the estimation of crop yields is an attractive prospect because yield is related to crop vigour, which is related to the spectral response of the crop vigour, which in turn is related to the spectral response of the crop measured by satellite sensors (Barnett and Thompson, 1982). There are reports of various studies on the suitability of satellite data for estimating crop yields. The correlation between the spectral reflectance of crops and agronomic variables has encouraged the application of these data in crop yield models (Tucker *et al*., 1980, Richardson *et al*., 1982).

The spectral reflectance of crops is strongly related to canopy parameters, which are in turn related to the final yield. These parameters are influenced by factors such as genotype, soil characteristics, cultural practices and other biotic factors i.e., spectral data is an integration of all the factors affecting crop growth. The spectral reflectance is a manifestation of all important factors affecting the agricultural crop and cultivative environmental impacts on crop growth (Liu and Kogan, 2002; Singh *et al*., 2002), therefore remote sensed data could be used to monitor crop condition through NDVI.

The normalised ratio of near-infrared reflectance to red reflectance, called the normalised difference vegetation index (NDVI) has been shown to be a sensitive indicator of biomass and leaf area in several crops, which can be used to track crop development over the season. Because crop yield is generally correlated with canopy development, this index can be used to develop a relationship with yield. Once a relationship between yield and NDVI is developed, farmers can predict their yield earlier in the growing season and therefore allow them to plan better for managing the crops and also for the following season's activities. Most importantly yield forecasts help national and international relief organisations to provide assistance in a timely and targeted way. Forecasting enables planners and decision makers to predict how much to import in the case of a shortfall or, optionally, to export in the case of a surplus.

Forecasting also enables governments to put in place strategic contingency plans for the redistribution of food during times of famine

Study Description

Tigray region (12^0 15'N, 14^o 57'N; 36^o 27'E, 39^o 59'E) is located in northern Ethiopia and has been selected as a study area for two reasons. First, the seasonal variability in rainfall patterns contributes to much variability in teff crop yields from season to season and secondly, because no study on the relationship between remote sensed data and teff yield of has been conducted in the region. Therefore, this research will be conducted using Landsat 16 days, with a spatial resolution of 30 m NDVI data. Satellie data will be validated using ground truthing in farmers' fields.

Research Application

It is hoped that the information generated will be used to develop a model suitable for assessing and forecasting teff and relate it to other field and environmental factors. Farmers and policy

makers will also receive better warning and forecasting services. Regional governments' preparedness for climate hazards will also be improved.

Acknowledgement

The author expresses sincere appreciation to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for funding the research.

References

Ahlrichs. J.S. and Bauer, M.E. 1983. Relation of agronomic and multispectral reflectance characteristics of spring wheat canopies. *Agronomy Journal* 75:987 - 993.

Bouvet, A., Le Toan, T. and Lam-Dao, N. 2009. Monitoring of the Rice Cropping System in the Mekong Delta Using ENVISAT/ASAR Dual Polarization Data. *IEEE Trans. Geoscience and Remote Sensing* 47:517 - 526. Barnett, T. L. and Thompson, D.R. 1982. The use of large-area spectral data in wheat yield estimation. *Remote Sensing of Environment* 12:509-518.

Delecolle, R., Maas, S.J., Guerif., M. and Baret, F. 1992. Remote sensing and crop production models: present trends. ISPRS J. Photogramm. *Remote Sens.* 47:145-161.

FDRE (Federal Democratic Republic of Ethiopia). 1997. *Environmental Policy*Environmental Protection Authority in collaboration with the Ministry of Economic Development and Cooperation: Addis Ababa, Ethiopia.

Habtegebrial, K., Singh, B.R. and Haile, M. 2007. Impact of tillage and nitrogen fertilisation on yield, nitrogen use efficiency of Tef (*Eragrostis tef*) and soil properties. *Journal of Soil Tillage Research* 94:56-63.

Hailu,T. and Seyfu, K. 2000. Production and Importance of Tef in Ethiopian Agriculture. In: Hailu, T., Getachew, B., and Sorrells, M. (Eds.). Narrowing the rift: Tef research and development. Proceedings of the international work shop on Tef Genetics and Improvement, Debre Zeit, Ethiopia. 16-19 October 2000. Ethiopian Agricultural Organisation 3-7.

Niel, T.G.V. and McVicar, T.R. 2003. A Simple method to improve field-level rice identification: toward operational monitoring with satellite remote sensing. *Australian Journal of Experimental Agriculture* 43:379-387.

Nuarsa I.W., Kanno, S., Sugimori, Y. and Nishio, F. 2005. Spectral Characterization of Rice Field Using Multi-Temporal Landsat ETM+ Data. *International Journal of Remote Sensing and Earth Sciences* 2:65-71.

Pan, X.Z., Uchida, S., Liang, Y., Hirano, A. and Sun, B. 2010. Discriminating different land use types by using multi temporal NDXI in a rice planting area. *International Journal of Remote Sensing* 31:585–596.

Reynolds, C.A., Yitayew, M., Slack, D.C., Hutchison, C.F., Huete, A., and Petersen, M.S. 2000. Estimating crop yields and production by integrating the FAO crop specific water balance model with real-time satellite data and ground based ancilliary data. *International Journal of Remote Sensing*, 21:3487-3508.

Richardson, A.J., Wiegand, C.L., Arkin, G.F., Nixon, P.R. and Gerbermann, A.H. 1982. Remotely-sensed spectral indicators of sorghum development and their use in growth. *Agricultural Meteorology* 26:11-23.

Seyfu Ketema, 1997.Teff (*Eragrostis tef* (Zucc.)). Trotter. Promotting the conservation and use of the under utilization crops. 12. IPGRI, Garersleben/international plant Genetic.

Tucker, C.J., Holben, B.N., Elgin, J.H. Jr., Mc- Murtrey. 1980. Remote sensing of dry matter accumulation in winter wheat. *Remote Sensing of Environment* 11:171-189.