Application Form

SPATIAL AGRICULTURAL INTELLIGENCE

1.Lead author Name: **Dr. Joseph OLOUKOI**

Agency/Institution: **African Regional Institute for Geospatial Information Science and Technology (AFRIGIST)**
Mailing address: **PMB 5545, ILE-IFE, OSUN STATE, NIGERIA**.

Email : oloukoi@rectas.org.ng / chabijos@gmail.com

Phone : **+234 806 404 2198**

2. Lead author Name: **Momodou SOUMAH**

Agency/Institution: **African Regional Institute for Geospatial Information Science and Technology (AFRIGIST)**
Mailing address: **PMB 5545, ILE-IFE, OSUN STATE, NIGERIA**.

Email : soumah@rectas.org.ng / papsoumah@gmail.com

Phone : **+234 803 497 3967/ +234 807 823 8496**

Collaborator

- **Professor AJALA**
  Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria
  +234 806 431 4415
  ajalacho@gmail.com

SPATIAL AGRICULTURAL INTELLIGENCE

Executive Summary

Effective management of agricultural resources calls for masses of current information. The existing information is inadequate. Much that is needed has not been collected and collection is time consuming and expensive. Remote sensing has potential to provide accurate and timely information on which to base economic decisions (National Research Council, 1970)
Remote sensing is the process of obtaining information about objects without coming into direct contact with the object (Campbell, 2006). The most useful wavelengths in remote sensing cover visible light (VIS) and extends through the near (NIR) and shortwave (SWIR) infrared, to thermal infrared (TIR) and microwave bands. Biophysical features of plants can be characterized spectrally by vegetation indices defined as unitless radiometric measures. They are calculated as ratios or differences of two or more bands in the Visible, Near InfraRed and Short-Wave InfraRed wavelengths. The Normalized Difference Vegetation Index is used to determine the condition, developmental stages and biomass of cultivated plants and to forecasts their yields.

The present project will make use of the cloud technology which in the last few years has been a hot topic advancing the capabilities in the remote sensing space (Hiestermann and Ferreira, 2017). This technology allows the remote access, processing and delivery of data products. These cloud-based enablers generally require certain experience in computer science and programming in order to use them efficiently.

This project will adapt the approach used by GEOGLAM on crop monitoring. However the spatial scale will be reduced. It will concentrate on Osun State in South West Nigeria, with a land mass of 925 100 ha. The State is basically located in an agricultural region with good climatic conditions. It will be used as a pilot area for the setting of crop monitoring system for the whole country (more than 900,000 Km2) as similar project has not been carried out in the area. Using the cloud technology and the big data within the framework of GEO, the project will adopt the Agricultural Monitoring Information System (AMIS) approach but applied only to Osun State composed of 30 local governments Areas. Interactive interface will be designed to provide real time information useful to decision makers and scientist for the monitoring of agricultural system.

Background/Objective: Basically the project will use cloud computing platform and automated mapping approach to disseminate near real time information to end users on the conditions of plants based on climatic, soil, and crop type in the study areas.

Methods: Useful information on the estimation of yield will be extracted from satellite imageries Sentinel 2 data precisely the Sentinel 2 (Sen2-Agri) for agricultural information. The choice of Sentinel2 for agricultural system is due to the fact that is suitable for the mapping crop types using automated approach. Also its spatial resolution (10m) is suitable for local to national coverage. The data is available every week and its overall accuracy is close to 85% depending on the type of landscapes.

Combination of multi spectral images (Sentinel 2 and Landsat 8), Unmanned Aerial Vehicle images and ground truthing will be used on specific areas for the identification of the types of

crops. Geographic Information System will be used in crop acreage and production estimation, to find out the locations of farms and to help in improving the accuracy of estimates and real-time crop zoning.

Inventory and mapping of areas will lead to agricultural resource interpretations to assist in the search for unused arable areas. Synoptic surveys of agricultural land from space permit the identification of present use of the land and show population settlement patterns, road and transportation networks. It will permit the identification of land characteristics such as major soil types, drainage and topographical relief patterns for evaluating the best potential use of the land.

Land use inventories are for contemporary information on land use, distribution of crops and acreage, to enable efficient management of agricultural resources. Information on present extent, location and productivity of land used is needed. Competition for use of land as well as changes such as urban development, development of new farmland by clearing, can be ascertained (National Research Council 1970).

Estimation of Crop condition and forecasting yield. Data on crop yields and forecasts during growing season are imperative to agriculture. The phases of agricultural production, the processing, storage of agricultural products depend on this information. The forecast will be a statement of the most likely yield or production. It considers the prospective planting, the actual planting, the acreage for harvest and the actual harvested acreage Crop acreage data by measurement of the areas identified on drone images which also record the distribution pattern and location. The spectral signature of crop species integrated with data will be digitized for classification maps to derive species and acreage (Boryan, Yang, & Mueller, 2011; Shao, Lunetta, Ediriwickreme, & Liames, 2010).

Expected results: Land use / land cover classification and area statistics. Yield zoning and near real-time growing conditions. Crop acreage and production estimation.

Applications / Improvement: It can be used by government agencies for taking decisions regarding import/export duty control and by agencies interested in procurement of crops and can be used to tackle inflation. Control of agricultural land use activities

For buyers and traders of agricultural commodities it optimizes procurement, enables abandon uncertainty of crop damage events, and to be ahead of competition.

Speed up and objectify claim management, assess crop risks on a local basis.

The utilization of Copernicus data to monitor crop areas optimize on-farm research with real-time data insights, reduce costs and time to generate smart farming maps.

The project in relation to the Sendai Framework for Disaster Risk Reduction refers to *the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.* Effectively implemented it will help to “Reduce direct disaster economic loss in relation to Global Gross Domestic Product (GDP) by 2030.” *(*SENDAI FRAMEWORK*)*

The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. A close monitoring of the crop in near real time will enable forecasting the yield and threats related to weather.

Crop production is a biological system with its operations carried out in open air environments that are subject to little control by the farmer. Crop organisms are subject to devastation by climatic extremes such as heat, drought, flooding and by biological pest as weeds, insects, fungi, bacteria, viruses and nematodes.

The Sustainable Development Goals in its goal 2 (Zero hunger) aim to end all forms of hunger and malnutrition by 2030, making sure all people – especially children – have access to enough and nutritious food all year round. This involves promoting sustainable agricultural practices: supporting small scale farmers and allowing equal access to land, technology and markets. It also requires international cooperation to ensure investment in infrastructure and technology to improve agricultural productivity.

Agricultural products from crops form a large part of every person's diet. Producing food of enough quantity and quality is essential for the well-being of the people anywhere in the world. Agricultural plants, as living organisms, require water and nutrients in order to grow and are sensitive to extreme weather phenomena, diseases and pests.
Remote sensing can provide data that help identify and monitor crops. When these data are organized in a Geographical Information System along with other types of data, they become an important tool that helps in making decisions about crops and agricultural strategies and knowledge of crop Production in agriculture will eliminate human starvation.

Project Plan

A. The planning of this project is tailored around the following activities:

(i) Training in the use of AWS and also Sen2 Agri operational system,

(ii) Land Cover Mapping

(iii) Crop Identification,

(iv) Crop vigour determination,

(v) Crop Yield Estimation and Yield Mapping

Agriculture is the activity of planning, producing and marketing crops and livestock and by-product derived from plant and animal sources. The primary objectives of modern agriculture are to cultivate the soil that it will produce more and to protect it from deterioration and misuse. Agricultural crop production is diverse comprising annual crops and perennial plants.

Remote sensing has the potential for the detection and characterization of agricultural phenomena. Remote sensing techniques can be used in identification and measurements of agricultural crop types such as grains (Rice, Corn, Millet and Sorghum); Roots and Tubers (Sweat Potatoes and Yams, Cassava); Fibers; Fruits and vegetables; Beverage crops (Coffee, Cocoa).((Chen & Zhuang, 2012; Oetter, Cohen, Berterretche, Maiersperger, & Kennedy, 2000; Wall, Laricque, & Léger, 2008).)

Because of the size, diversity, variability and vulnerability of the crops, accurate information on production during and following the crop season is limited to the crop grown. The need for increased accuracy, timeliness, frequency and degree of detail of crop information is growing (National Research Council 1970).

One means of meeting the current and future needs for crop information is through remote sensing by a system of operational observation satellites. With multiband sensors they offer the potential of providing macroscopic surveys of the earth on a synoptic basis and detailed observations of selected areas. They will provide required agricultural data.

To manipulate the resources and environment to gain a better life, there is need to accelerate the preparation of natural resource inventories to assist national groups. Man needs more accurate, timely and detailed information on the use of the terrain and its potentials.

1. Land Cover Mapping: It is one of the most important and typical applications of remote sensing data. Land cover corresponds to the physical condition of the ground surface (forest, grassland, concrete pavement etc.), while land use reflects human activities such as the use of the land (industrial zones, residential zones, agricultural fields etc). Initially the land cover classification system should be established, which is usually defined as levels and classes. The level and class should be designed in consideration of the purpose of use (national, regional or local), the spatial and spectral resolution of the remote sensing data, users' requirements and so on. Information on land cover and changing land cover patterns is directly useful for determining and implementing environment policy and can be used with other data to make complex assessments (mapping erosion risks, disaster mitigation, climate change adaptation etc.).

Land cover change detection is necessary for updating land cover maps and the management of natural resources. The change is usually detected by comparison between two multi-date images, or sometimes between an old map and an updated remote sensing image. The approach can be seasonal, agricultural lands and deciduous forests change seasonally or annual, land cover or land use changes, which are real changes (deforested areas or newly built towns).

2. Crop Identification: It is very important to know what crops the local government area is going to produce in the current growing season. This knowledge has financial benefits for the country, as it allows the budget planning for importing and exporting of food products. In order to identify a crop, we need to be familiar with its growth cycle (germination, growth, pollination, senescence). Some crops last for a couple of months, other need more than 6 months to complete their growth. We need to know in advance, how the crops reflect the near-infrared at each of their various growth stages. Using the different near infrared reflectance is one of the tools we must discriminate between two crops. Having the knowledge of when each crop is planted and harvested, we can estimate the percentage of vegetation cover through the growth period, assuming no external factors (stress, disease, etc.) affect its growth. By using multi-date data (data from different dates) from one growing period, it is possible to identify the different crop types, because the vegetation cover of each crop changes at different rates. By combining this information with remote sensing data, we can discriminate between different crops and identify them. This information serves to predict crop yield, collecting crop production statistics, facilitating crop rotation records, mapping soil productivity, identification of factors influencing crop stress, assessment of crop damage and monitoring farming activity.

3. Determining Crop Vigour

Determining agent responsible for a loss in crop vigour (pathogens, insects, mineral deficiency, mineral toxicity, drought, flooding) mapping of the vigour losses and mapping of the locations of the agent. Help in identification of the crop and the agent.

For the identification of stressed plants, chlorophyll is an essential part of the process of photosynthesis. It absorbs solar energy in order to provide power for the process of photosynthesis. Because it absorbs energy, it has an important effect on the amount of energy that is reflected. With remote sensing we can directly estimate how much chlorophyll there is in a plant. By combining more than one bands of the recorded remote sensing data, we can create vegetation indices and use them to estimate crop status. Depending on the visible and near-infrared reflectance, the produced vegetation indices give us an indication on the amount of chlorophyll present in the plants. With this information we can estimate if and how much stress the plants are under.

Before chlorophyll starts to break down in stressed plants, whatever is causing the stress has already started to affect the cellular structure of the leaves. This affects the plant reflectance in the
near infrared, even before the loss of chlorophyll changes the reflectance in the visible region. With remote sensing we can see the changes in the near infrared (which are not visible to our eyes) before the chlorotic symptoms appear, and this way we can have an early warning that the plants are under stress. Using vegetation indices with data from sensors with a very high spatial resolution, we can also see areas of the fields where crops suffer from stress and estimate how serious it is. Being able to identify stress variations within a field allows the farmer to locate the problem and take appropriate action in order to deal with the problem at the specific location. Therefore, remote sensing allows detection of environmental stresses in crops, such as shortage of water and irrigation, chlorosis, nitrogen deficiency.

4. Estimating crop yield: determined by computation from the yield per unit area and the acreage. Visit the field on the ground as the crop nears maturity. Measure the yield per unit area in each several small sample plots randomly located in the field, calculate from these measurements the average yield per acre in the field and multiply the last figure by the total acreage.
(temperature minimum and maximum; relative humidity; rainfall; number of daylight hours).
An estimation of biomass is obtained. From the biomass plant properties and finally the yield can be estimated. The estimation of biomass must be done several times a year to forecast crop parameters.
Information on expected yield is very important for government agencies, commodity traders and producers in planning harvest, storage, transportation and marketing activities.
The sooner this information is available, the lower the economic risk, translating into greater efficiency and increased return on investments.

5. Yield Mapping: Spatial distribution of plant biomass and other bio-physical parameters within fields is usually not even, but very patchy, defined by soil conditions, therefore it is possible to compile yield maps. Such maps created based on satellite images acquired in many seasons represent the spatial variability in crops yield regardless of plant species. Yield maps are applied to determine patterns of fertilization and irrigation, and indirectly, can be used in planning programs for the eradication of weeds, pests and plant diseases. In such programs, fertilizer or pesticides doses are adopted to the productivity of a specific spot on the field. Apart from economic profits to the farmer, environmental benefits are also important that rely on reducing the negative impact of agriculture production inputs on the environment.
By measuring the reflectance of the plants at various wavelengths, it is possible to collect a lot of information about the status of the plants. From previous research, there are known relationships between the indices using those two regions of the spectrum and the amount of vegetation, a measure of which is the Leaf Area Index. From these estimates we can derive the population of the plants. The data provided by the sensors can also be used to make an estimate on the future crop yield.
By calculating the Normalised Difference Vegetation Index (NDVI), or the Soil-Adjusted Vegetation Index (SAVI) when vegetation cover is low, we can get information on the crops' vigour.

B. Ground Data

Using ground-truth data to assist interpretation of image data is a common way to improve research accuracy. A sampling strategy using smaller-size units, but a larger number of samples provide more precise estimates (Stehman, Sohl, & Loveland, 2005). This is fulfilled by consulting local farmers to screen a numbers of candidate fields for each crop firstly, then followed with a two-step sampling scheme, that is:

i) to sample a set of single pure crop plots that can be served as reference standards of crop identification, when the field shape and size, as well as crop type can be observed clearly;
ii) to verify a set of unknown crop plots that was identified as certain crops

C. Data Processing and Expected Results

The data processing will be based on the use of Sen2-Agri operational system a standalone and open processing software that generates a set of products for agriculture monitoring from Sentinel-2 (S2) and Landsat 8 (L8) data. We will make use of the composites of cloud free surface reflectance values, the dynamic cropland masks, delivered on a monthly basis during agricultural seasons and the cultivated crop type maps and area extent for main crop groups, delivered twice along agricultural seasons (at the middle and at the end of the season). Also, the biophysical vegetation processor will be used in order to provide regular information on the biophysical vegetation status through indicators such as Normalized Difference Vegetation Index (NDVI) and Leaf Area Index (LAI), and some phenology indices, also referred to as NDVI metrics, which inform about specific key parameters of the growing season (starting date, season length and date of maximum growth rate). All these indicators describing the vegetative development of crops will be incorporated in the monitoring system.

Climatic information parameters such rainfall, temperature, humidity, insolation etc. with information on soil types will be generated in digital map forms and combined with the information above to strengthen the agricultural information system put in place and also to provide scenarios on the conditions of crops as the growing season unfolds

The link of the generated information system with the cloud will be made using the tools provided by AWS. AWS S3 and AWS LAMBDA will be of use during the execution of the project. Amazon S3 will help in the detection of phenomena object-created layers such as the rainfall, temperature, soil types, crop types, etc, while AWS Lambda will execute the Lambda function by assuming the execution role that we will specify. The project will follow the AWS cloud architectural principles by focussing on the elasticity of the system, the consideration of services and the building of a strong and reliable spatial database.

D. Contribution

Remote sensing data has become an efficient and reliable approach of deriving such information across large area where field-based methods are of limited utility.
Crop mapping on an annual basis can provide improved estimates of near real time changes in crop production and can greatly benefit strategic planning in agro-ecosystems. Crop type maps are among the most important datasets in crop management and yield estimation
Wide-ranging, long-term, and spatially accurate cropland classification data is a valuable source of information for government agencies, private sector organizations, scientists, educators, and others who use land-cover information.
.

E. Work plan

	Work package	*Description*	*Results*
Year 1 *First quarter*	**Training in the use of AWS and** **- Agri operational system**	Enrolment in Digital Training of AWS and certification Interaction with GEOGLAM Expert and GEO	Good understanding and mastery in the use of AWS, and GEOGLAM tools.
Year 1 *Quarter 2*	**Data collection and Processing**	Primary Data: Sentinel data. Landsat ime series, UAV data Secondary Data: Topographic sheet, Socio-economic data, meteorological data. Field survey and sample interpretation (1) For the selected field sample, UAV field survey was carried and aero-photography was captured and crop plots were delineated. (Field work photos, UAV photo mosaic, Vectorization of sample land) Contact to partners	Freely downloaded higher temporal resolution. freely downloaded moderate spatial resolution (10-30 m) but coarse temporal resolution (16 days) sensors like Landsat Thematic Mapper (TM/ETM+) and Operational Land Imager (OLI). Acquisition data of high temporal resolution, like Sentinel1/ 2

Year 1 *Quarter 3* *Quarter 4*	**Land Cover Mapping** **Crop Identification:** **Determining crop vigour** **Identifying Stressed Plants**	Crop area frame survey system A primary system for crop area frame survey will be developed, which will include geospatial sampling frame, segment sampling, field survey, survey data, estimation, quality evaluation. Detailed data on fields will be collected and measuring precision will be improved with the use of PDA and GPS. Developing of sampling frame	Field maps：Hardcopy image of sampling villages, vector maps, maps of sampling segments. Land Cover Map Crop types map
Year2 *Quarter 1* *Quarter 2*	**Estimating crop acreage:**	Screen survey Sampling segment screen questionnaire: Collect data at the beginning of each survey round. Location, crop used area, non-crop used area, field splitting, and users data are collected. Seasonal survey Cropping intention survey: Farmers' planting intention and plan are carried at sampling segment before planting. Farmers will be selected for survey at each sampling village. Crop area survey: Carried at planting period. Crop area are collected from sampling segments directly. Crop yield and production survey: Carried at harvest	Measure of acreages
Year2 *Quarter 3* *Quarter 4*	**Estimating crop yield**:	Production of yield maps	Yield Maps
Year 3	**Publications** **Reporting.**	• Contact to regional partners • Preparation of report	• Final report • Decisions on further steps

Milestone overview

- Y1Q1: Training in the use of AWS and use of Sent
- Y1Q2: Data collection and Processing
- Y1Q3/ Y1Q4: Land Cover Mapping; Crop Identification; Determining crop vigour; Identifying Stressed Plants
- Y2Q1/Q2/Q3/Q4: Estimating crop acreage; Estimating crop yield
- Y3: Publications, Reporting.

F. Time chart of the project:

Tasks	*Year 1 Quarter1*	*Year 1 Quarter 2*	*Year 1 Quarter 3*	*Year 1 Quarter 4*	*Year 2 Quarter1*	*Year 2 Quarter 2*	*Year 2 Quarter 3*	*Year 2 Quarter 4*	*Year 3*
Training in the use of AWS and Sen2 Agri operational system									
Data collection and Processing									
Land Cover Mapping									
Crop Identification									
Determining crop									
Estimating crop acreage									
Estimating crop yield									
Reporting, Publication									

G. Detailed budget of anticipated expenditure

Expenditure	**US DOLLAR**
AMAZON EC2 INSTANCES	USD 615.20/Month
Total amount (for 36 months)	***USD 22,147.2***
AMAZON S3	USD 508.1/Month
Total amount (for 36 months)	***USD 18291.6***
GRAND TOTAL AMOUNT FOR 3 YEARS	***USD 40,438.8***

Link:
https://calculator.s3.amazonaws.com/index.html#r=IAD&s=EC2&key=calc-67770C87-A0D2-4D86-A1EF-1C8155D16ABE

https://calculator.s3.amazonaws.com/index.html#r=IAD&s=S3&key=calc-63052BC3-F74F-486D-8A43-DEC0F9096FD2

The African Regional Institute for Geospatial Information Science and Technology (AFRIGIST) supports the research project in providing the laboratory, equipment required and access to Internet.

BIBLIOGRAPHY

BARRETT, R. CROWTHER, P. LAURENCE, R. LINCOLNE, R.2000. Agricultural Crop Identification Using SPOT and LANDSAT Images in Tasmania. International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam 2000.

Boehmer, N. A. (1996). Vegetation indices for Landsat images. *Proceeding of Southwest Symposium on Image Analysis and Interpretation* (pp. 258-262). https://doi.org/10.1109/iai.1996.493763

Boryan, C., Yang, Z., Mueller, R., & Craig, M. (2011). Monitoring US agriculture: the US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer Program. *Geocarto International, 26*(5), 341-358. https://doi.org/10.1080/10106049.2011.562309

Campbell, J. B. (2006). Introduction to Remote Sensing, The Guilford Press, Fourth Edition, ISBN-13:978-15938-53198. Printed in the United State of America

Chen, H., & Zhuang, D. (2012). Strategy to extract winter wheat and summer maize distribution based on time-series MODIS NDVI data. *First International Conference on Agro-Geoinformatics* (pp. 1-5). https://doi.org/10.1109/agro-geoinformatics.2012.6311609

Hiestermann J., Ferreira S.L. (2017). Cloud-based agricultural solution: A case study of near real-time regional agricultural crop growth information in South Africa. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-3/W2, 2017 37th International Symposium on Remote Sensing of Environment, 8–12 May 2017, Tshwane, South Africa. https://doi.org/10.5194/isprs-archives-XLII-3-W2-79-2017

Huete, A. R. (1988). A Soil-Adjusted Vegetation Index (SAVI). *Remote Sensing of Environment, 25*(3), 295-309. https://doi.org/10.1016/0034-4257(88)90106-x

Ke, Y., Im, J., Lee, J., Gong, H., & Ryu, Y. (2015). Characteristics of Landsat 8 OLI-derived NDVI by comparison with multiple satellite sensors and in-situ observations. *Remote Sensing of Environment, 164*, 298-313. https://doi.org/10.1016/j.rse.2015.04.004

Lees, B. G., & Ritman, K. (1991). Decision-Tree and Rule-Induction Approach to Integration of Remotely Sensed and GIS Data in Mapping Vegetation in Disturbed or Hilly Environments. *Environmental Management, 15*(6), 823-831. https://doi.org/10.1007/bf02394820

National Research Council, 1970. *Remote Sensing with Special Reference to Agriculture and Forestry*. Washington, DC: The National Academies Press. https://doi.org/10.17226/20260.

Oetter, D. R., Cohen, W. B., Berterretche, M., Maiersperger, T. K., & Kennedy, R. E. (2001). Land cover mapping in an agricultural setting using multi-seasonal Thematic Mapper data. *Remote Sensing of Environment*, *76*(2), 139-155. https://doi.org/10.1016/s0034-4257(00)00202-9

Pal, M., & Mather, P. M. (2003). An assessment of the effectiveness of decision tree methods for land cover classification. *Remote Sensing of Environment*, *86*(4), 554-565. https://doi.org/10.1016/s0034-4257 (03)00132-9

Shao, Y., Lunetta, R. S., Ediriwickrema, J., & Iiames, J. (2010). Mapping Cropland and Major Crop Types across the Great Lakes Basin using MODIS-NDVI Data. *Photogrammetric Engineering and Remote Sensing*, *76*(1), 73-84. https://doi.org/10.14358/pers.76.1.73

Soria-Ruiz, J. Fernandez-Ordonez, Y. and McNairn, H. (2009). Corn Monitoring and Crop Yield Using Optical and Microwave Remote Sensing, Geoscience and Remote Sensing, Pei-Gee Peter Ho (Ed.), ISBN: 978-953-307-003-2
Available from: http://www.intechopen.com/books/geoscience-and-remotesensing/ corn-monitoring-and-crop-yield-using-optical-and-microwave-remote-sensing

Stehman, S. V., Sohl, T. L., & Loveland, T. R. (2005). An evaluation of sampling strategies to improve precision of estimates of gross change in land use and land cover. *International Journal of Remote Sensing*, *26*(22), 4941-4957. https://doi.org/10.1080/01431160500222632

Wall, L., Laricque, D., & Leger, P. M. (2008). The early explanatory power of NDVI in crop yield modelling. *International Journal of Remote Sensing*, *29*(8), 2211-2225. https://doi.org/10.1080/01431160701395252

Xia Zhao, Xingchun Wang, Guangchao Cao, Kelong Chen, Wenjia Tang and Zhijun Zhang, (2017). Crop Identification by Using Seasonal Parameters Extracted from Time Series Landsat Images in a Mountainous Agricultural County of Eastern Qinghai Province, China Journal of Agricultural Science; Vol. 9, No. 4; 2017 ISSN 1916-9752 E-ISSN 1916-9760 Published by Canadian Center of Science and Education