

Quantitative Image Classification Accuracy Assessment Program for Sustainable Geospatial Technology Applications

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Key words: computer programming, image classification, accuracy assessment, QiMAP

SUMMARY

Image classification is an important operation in remotely sensed data analysis. It involves the extraction of identified features and features of interest into themes or classes. The final map resulting from classification exercise is called thematic map. Both the raw data and final output – thematic maps are susceptible to machine and human errors. Therefore, the level at which a classified map represents the reality it portrays remains uncertain until its accuracy is determined. Accuracy assessment is the measurement of the rate and level to which classified image agrees with the reference (ground) data it represents. Accuracy of any image classification may be tested in four different ways - field checks at selected points, map overlays, statistical analysis of numerical data, and using confusion matrix calculations. The confusion matrix is the most widely used measure of image classification accuracy assessment. It is a simple cross-tabulation of the mapped class label against the observed in the ground or reference data for a sample set. Several measures of classification accuracy may be derived from a confusion matrix, this include, overall accuracy, producer's accuracy, user's accuracy, and Kappa co-efficient. In many studies, quantitative assessment of the accuracy of classification is often avoided due to the rigorous statistical methods involved. Development of standard computer applications eases the task of accuracy assessment.

This paper presents the development and application of the Quantitative Image Classification Accuracy Modeling and Assessment Program (QiMAP) for sustainable geospatial technology applications. QiMAP was developed using the Microsoft Visual Basic 6.0 programming language, for research and academic purpose. The program was used in evaluating the classification accuracy of data used in the analysis of land use/land cover pattern along river Benue channel in Adamawa state, Nigeria. The results revealed a system that simplifies the task of accuracy assessment of image classification. The paper conclude that to ensure a reliable and sustainable application of geospatial technology - remote sensing, image classification accuracy assessment should be consider as prerequisite for acceptability of any thematic map derived from remote sensing data analysis. And the development of standard applications such as QiMAP would accelerate the appraisal of accuracy assessment for image classification.

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1. INTRODUCTION

Remote Sensing which is one of the key technologies technically grouped as “geospatial technology” is becoming more and more important data source for geo-related analysis, researches and projects. Classification is an efficient way of extracting information from a remotely sensed data. The resulting maps from such classification are referred to as classification maps or thematic maps. These maps have been one of the vital sources of information in various disciplines requiring the application of Geographic Information System (GIS) and Remote Sensing technology.

Image classification is an inevitable process for analysing and interpreting remote sensing data. Quality and validity of results from classified images have significant impacts on the end-uses of such images – such as in making spatial related decisions. The accuracy of collection and classification of data determines the reliability of the final result. Hence, accuracy assessment plays a potent role in remote sensing image classification. It is therefore important to know the quality of the classification maps or data before they are subjected to further analysis and used in making relevant decisions.

2. BACKGROUND TO ACCURACY ASSESSMENT

Map is one of the most important products in any geo-spatial discipline. Maps can be regarded as the nucleus and focal point of most geospatial technology applications. Any map is defined as a model or generalization of reality. Therefore, it will usually contain errors (Maling, 1989). Thus, although a thematic map provides a typically unquestioned simplification of reality, it has flaws and is only one model or representation of the depicted theme or reality. The mapping processes involves generalizations which are subjected to some loss of information and completeness (Maling, 1989). It is therefore important that the quality of thematic maps that are derived from remotely sensed data be assessed and expressed in an understandable way. This is important not only in providing a guide to the quality of a map and its fitness for a particular purpose, but also in understanding error and its likely implications (Arbia et al, 1998; Janssen & van der Wel, 1994; Veregin, 1994).

Accuracy assessment is the measurement of the rate and level to which classified image agrees with the reference (ground) data it represents. In statistical terms, accuracy comprises bias and precision and the distinction between the two is sometimes important as one may be traded for the other (Campbell, 1996; Maling, 1989). In mapping of features from a remotely sensed data, the term accuracy is often used to portray the level of ‘validity’ and ‘correctness’ of a map or classification. ‘Valid’ or ‘Correct’ (thematic) maps are those that represent the reality to a significant level of acceptance. That is, a map (thematic) derived from remotely sensed data classification may be considered accurate if it provides an unbiased representation

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of the actual area of the region it depict. Therefore, classification accuracy describes the degree to which the derived image classification agrees with reality or conforms to the ‘truth’ (Campbell, 1996, and Maling, 1989). A classification error is, thus, some discrepancy between the situation depicted on the thematic map and reality (Foody, 2002).

Disagreements and variations between the two data sets (classified maps and reference data) are typically interpreted as errors in the maps derived from the remotely sensed data (Congalton, 1991; Smedes, 1975). This interpretation has over the years driven researches that aims to decrease the error in image classification. These researches has typically focused on the derivation and assessment of different classification algorithms.

Several indices have been proposed to measure the accuracy of classification maps. The most widely used measures include overall accuracy, producer's accuracy, user's accuracy, and kappa. Overall accuracy is also called overall agreement, raw accuracy, or proportion of pixels correctly classified. It is the proportion of pixels whose class labels agree with the ground reference. Producer accuracy (PA) is also referred to as omission error and user accuracy, commission error. Various algorithms have been developed to ascertain the level and proportion of accuracy in image classification. These algorithms attempt to relate class values (pixels) for the classified image produced by the classifier to a ground reference image or data. Sources of reference data include among others, ground truth, high resolution satellite images, and maps derived from aerial photo interpretation.

This paper presents the development of the Quantitative Image Classification Accuracy Modelling and Assessment Program (QiMAP) for sustainable geospatial technology (remote sensing) application. QiMAP is developed for academic and research purposes using the Visual Basic 6.0 programming language. The program is used to develop quantitative image classification models and evaluates the accuracy of any model based on the user defined values in the confusion matrix. The program evaluates the confusion matrix and interpretes the results based on the Kappa co-efficient of agreement.

3. REVIEW OF LITERATURE

Several studies have been conducted in the development and evaluation of image classification accuracy assessment methods and its applications. These studies have been channeled at various components of the mapping processes including the assessment of accuracy.

Foody, 2002, reviewed the background and methods of classification accuracy assessment that are commonly utilized and recommended in the research literatures. He asserts that in larger proportion of researches, the recommended approaches have not been generally adopted. This is perhaps a reflection of problems that are connected with accuracy assessment. Therefore, many researches largely failed to achieve the accuracy targets that are commonly specified. He further explored eight broad problem areas that currently limit the ability to appropriately assess, document, and use the accuracy of thematic maps derived from remote sensing. Foody (2002), in his evaluation of the status of land cover classification

accuracy assessment, stated that although thematic maps are an imperfect model of the environment, they are widely used and often derived from remotely sensed data through some form of classification analysis. And that the value of the map is clearly a function of the accuracy of the classification.

In similar study, Jiang and Liu, 2001 examines chance-adjusted measures for accuracy assessment in remote sensing image classification. The study focus on the evaluation of image classification accuracy assessment measures whether they are theoretically sound and practically interpretable. The usefulness of kappa-like measures was re-evaluated and method of proper accuracy measures for accuracy assessment was recommended.

Gomez and Montero, 2011, in their study asserts that large number of accuracy measures for crisp supervised classifications have been developed. Among others, these measures include Overall accuracy, Kappa index, Kappa location, Kappa histogram and user accuracy. The central focus was on the development of accuracy measures that permits the establishment of the validity of image classification when a reference data exists. In their work, they extend and analyze some of these measures in a fuzzy framework to be able to measure the reliability of a given classifier in a supervised fuzzy classification system with fuzzy reference data. More so, the measures considered take into account the preferences of the decision maker in order to differentiate some errors that must not be considered equal in the classification process. Any supervised classification does not complete until an assessment of its accuracy has been performed (Gomez and Montero, 2011).

Smedes, 1975 claim that despite the attractions of the recommended standard methods of accuracy assessment and reporting, it seems that the remote sensing community has not heeded the calls to adopt them and often does not achieve the typically specified targets. The failure to attain the specified target levels of accuracy is typically taken to indicate a failure of remote sensing, in some respect, as a source of land cover information (Smedes, 1975).

Trodd (1955) in an attempt to examine the rate at which accuracy assessment is performed on classified images surveyed 84 classifications that are reported in 25 research papers published in major journals between 1994 and 1995. He reviewed the methods used in evaluating image classifications in these papers. According to Trodd, 60% of the papers provided a confusion matrix while only 44% gave other quantitative measures of accuracy assessment. He discovered that 68% of the papers adopted proportional methods of accuracy assessment using percentages while 48% of the papers uses the Kappa coefficient and 8% of the papers provided no quantitative measure of accuracy. In most of the papers that adopted a quantitative measure of accuracy, the accuracy of classification presented was generally below 85%, which is the commonly recommended target of accuracy.

Several other studies have been observed to generally discuss classifications with overall accuracies below the recommended target of 85% and have a large range in the accuracy with which the individual classes have been classified (for example, DeGloria et al., 2000).

4. CLASSIFICATION ACCURACY ASSESSMENT MEASURES

Many methods of accuracy assessment have been discussed in the remote sensing literature (e.g., Aronoff, 1982, 1985 & Czaplewski, 1995). However, the most widely promoted and used is usually derived from a confusion or error matrix (Caetano, 2007). Accuracy of any image classification may be tested in four different ways;

1. Field checks at selected points – this is usually a non-rigorous statistical technique and it is subjective, that is, it may not be applicable to all classification cases. Selected points of verification are chosen either randomly or along a grid
2. Map overlays – this is a qualitative comparative method which aims to estimate the agreement of theme or class that are identified between a class map and reference maps. The class map and the reference maps are usually superimposed – one on the other
3. Statistical analysis of numerical data developed in sampling, measuring, and processing data, using such tests as root mean square, standard error, analysis of variance, correlation coefficients, linear or multiple regression analysis, and Chi-square testing, and
4. Confusion matrix calculations. The confusion matrix is a simple cross-tabulation of the mapped class label against the observed in the ground or reference data for a sample set (Caetano, 2007).

The Quantitative Image Classification Accuracy Modelling and Assessment Program presented in this paper uses the confusion matrix to compute considered accuracy measures for given classification data.

4.1 Confusion Matrix

The confusion matrix is a rigorous statistical technique where number or value of pixels correctly assigned to each classification class and those misassigned to other classes are arranged in rows and columns relating allotted pixels in the classification image to a reference/ground data.

Confusion matrix is currently at the core of the accuracy assessment literature (Foody, 2002). As a simple cross-tabulation of the mapped class label against that observed in the ground or reference data for a sample of cases at specified locations, it provides a clear foundation for accuracy assessment (Campbell, 1996; Canters, 1997). The confusion matrix provides the basis on which to both describe classification accuracy and characterize errors, which may help refine the classification or estimates derived from it (Foody, 2002).

For example, the matrix may reveal interclass confusion that could be resolved with the use of additional discriminatory information. Alternatively, the pattern of misclassification evident in the matrix may aid studies that use the map, particularly as a means to estimating the areal extent of classes over a region (Czaplewski, 1992).

Several measures of classification accuracy may be derived from a confusion matrix. One of the most popular is the percentage of cases correctly classified. The following are some of the accuracy calculations and indices that can be generated from a confusion matrix;

1. Overall accuracy
2. Mapping accuracy
3. Producer accuracy
4. User accuracy, and
5. Kappa co-efficient of agreement

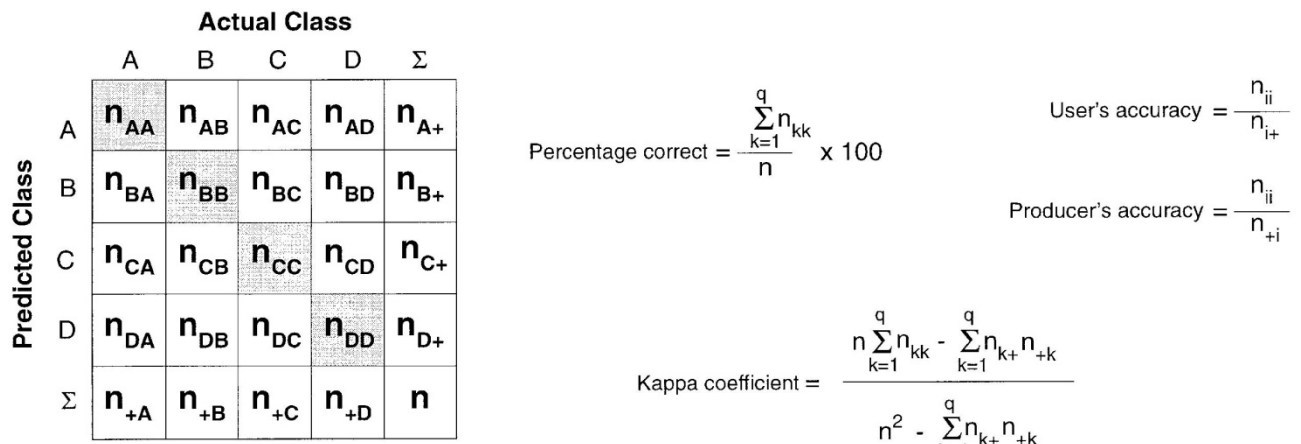


Fig 1: Confusion Matrix and possible measures of Accuracy

Source: Giles M. Foody, 2002

Where;

- $n_{AA} - n_{DD}$: are the elements in the matrix
- $n_{A+} - n_{D+}$: sum of rows
- $n_{+A} - n_{+D}$: sum of columns
- n = summation of all the values in the matrix
- q = total number of classes

The confusion matrix and some common measures of classification accuracy that may be derived from it is described in Fig 1. Elements along the major diagonal (highlighted) contains the cases where the class labels represented in the image classification and ground reference adopted agreed. These elements, where the subscripted values are the same (i.e. n_{AA} , n_{BB} , n_{CC} , n_{DD}), represents cases that are correctly classified. The other elements outside the matrix's major diagonal contain cases where there are disagreements between the classified image and reference data.

The illustration assume a simple random sampling technique. However, varieties and alternative formula exist for matrices deduced from different sampling methods such as stratified and cluster sampling methods.

4.2 Overall Accuracy

This is the total classification accuracy. Overall accuracy is obtained by dividing the total number of correct pixels (diagonal) by the total number of pixels in the error matrix.

4.3 Agreement/Accuracy

The agreement/accuracy is the probability (in percentage) that the classifier has labelled an image pixel into the ground truth Class. It is the probability of a reference pixel being correctly classified. The agreement/accuracy is derived by dividing the value correctly classified in a class by the total pixels for that class in the reference data/image (column total).

4.4 Producer's Accuracy

Omission error is another term used to mean producer accuracy, it occurs whenever pixels that should have been identified as belonging to a particular class were simply not recognized as present. Producer accuracy is obtained by dividing the total pixels not correctly classified for each class in the reference data (column) by the total pixels for that class in the reference data/image (column total).

4.5 User's Accuracy

User accuracy is also referred to as Commission Error. Commission error occurs when pixels associated with a class are incorrectly identified as other classes, or from improperly separating a single class into two or more classes. Commission error is calculated by dividing the number of pixels not correctly classified for each class in the classification (row) by the total number of pixels for that class in the classification (row total).

4.6 Mapping Accuracy

Mapping accuracy for each class is stated as the number of correctly identified pixels within the total in the displayed area divided by that number plus error pixels of commission and omission.

$$\text{Mapping Accuracy} = \frac{X_k}{(X_k + X_o + X_c)}$$

Where;

X_k = pixels correctly classified for class X

X_o = Omission Error for class X

X_c = Commission Error for class X

4.7 Kappa Co-efficient ($Kappa_{(Hat)}$)

Several criticisms have been laid against the use of percentages as a measure of assessing classification accuracy. The challenge is that, for some users, some samplesets or cases may have been allocated to the correct class by chance (Congalton, 1991; Pontius, 2000; Rosenfield & Fitzpatrick-Lins, 1986; Turk, 1979). To compensate for the effects of chance agreement, chance-adjusted (Stehman, 1997) measures were developed. Cohen's kappa coefficient is a chance-adjusted measure that was developed and has often been used and adopted as a standard measure of classification accuracy (Smits et al., 1999).

The kappa coefficient makes notable compensation for chance agreement and a variance term may be calculated for it enabling the statistical testing of the significance of the difference between two coefficients (Rosenfield & Fitzpatrick-Lins, 1986). This is often important, as frequently, there is a desire to compare different classifications and so matrices (Foody, 2002). Kappa is generally the measure of agreement between the classification map and the reference data. Kappa is a discrete multivariate technique used in accuracy assessment.

$$\text{Kappa coefficient} = \frac{n \sum_{k=1}^q n_{kk} - \sum_{k=1}^q n_{k+} n_{+k}}{n^2 - \sum_{k=1}^q n_{k+} n_{+k}}$$

Source: Foody, 2002

4.8 Strength of Agreement Based on Kappa

Many schemes describing the strength of agreement of classification based on the Kappa coefficient has been developed. Among them is the Landis and Kosh (1977)'s scheme and Fleiss (1981)'s scheme. This paper uses the Landis and Kosh scheme of Agreement based on the Kappa co-efficient presented in Table 1.

Table 1: Landis and Kosh (1977) Scheme of Agreement based on Kappa

Kappa Co-efficient	Agreement
< 0.00	Poor
0.00 – 0.20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost Perfect

Source: Jiang and Liu, 2011

5. METHODOLOGY

Microsoft Visual Basic 6.0 programming language was chosen for the development of the Quantitative Image Classification Accuracy Modeling and Assessment Program (QiMAP) presented in this paper.

5.1 Visual Basic 6.0 Programming Language

Visual Basic programming language was developed by Microsoft Corporation in 1991 as a windows Rapid Application Development (RAD) language. Visual Basic evolved from the Disk Operating System (DOS) based Beginner All-Purpose Symbolic Instruction Code (BASIC) programming languages, as a Microsoft window programming language. Standard applications are developed in visual basic in an integrated development environment (IDE),

which allows the programmer to create, design and run visual basic programs with ease. It also allow programmer to create working and useful applications in short period of time compared to the longer period of program development involved using programming languages without an IDE.

Visual basic is the most widely use Rapid Application Development (RAD) programming language in the world. It provides a user friendly environment with access to objects and methods for rapidly creating an application. Visual Basic provide features such as the Graphical User Interface (GUI), events handling capabilities, access to Win 32 API, object oriented features, error handling, and structured programming. Windows based application development was a difficult task before the creation of Microsoft Visual Basic. Visual basic greatly simplifies windows based application development. Hence, visual basic programming language is adopted in this paper for the development of the Quantitative Image Classification Accuracy Modelling and Assessment Program (QiMAP).

5.2 User Interfaces Available in QiMAP

Table 2: Description of some of the user interfaces available in QiMAP

No.	Forms	Description
1	Form MDI	This is the container form that hold every other forms and objects within the program
2	Form Tool	Presents event objects that grants user access to some of the operations in the program e.g. in creating a new classification model or opening of an existing classification file
3	Form New Classification Model	Contains controls and objects that allow user to create a new classification model. This form have controls (e.g. textboxes and command buttons) to collect the new model information e.g. model Id and model name
4	Form Class Properties	This form/interface enable user to input the labels or names for each of the classes used in the classification
5	Form Confusion Matrix Data Sheet	Presents interface for entering data into the confusion matrix. This form also has buttons that allows user to open an existing classification file, save the completed confusion matrix and evaluate the classification data.
6	Form Matrix Evaluation	Contains interface that present results of the confusion matrix evaluation. The confusion matrix is reproduced in this form with the corresponding accuracy measures (e.g. user accuracy) for respective classes and the interpretation of the classification accuracy assessment result based on the Kappa co-efficient.
8	Form About	Describe the function of the program.

5.3 QiMAP Model Structure

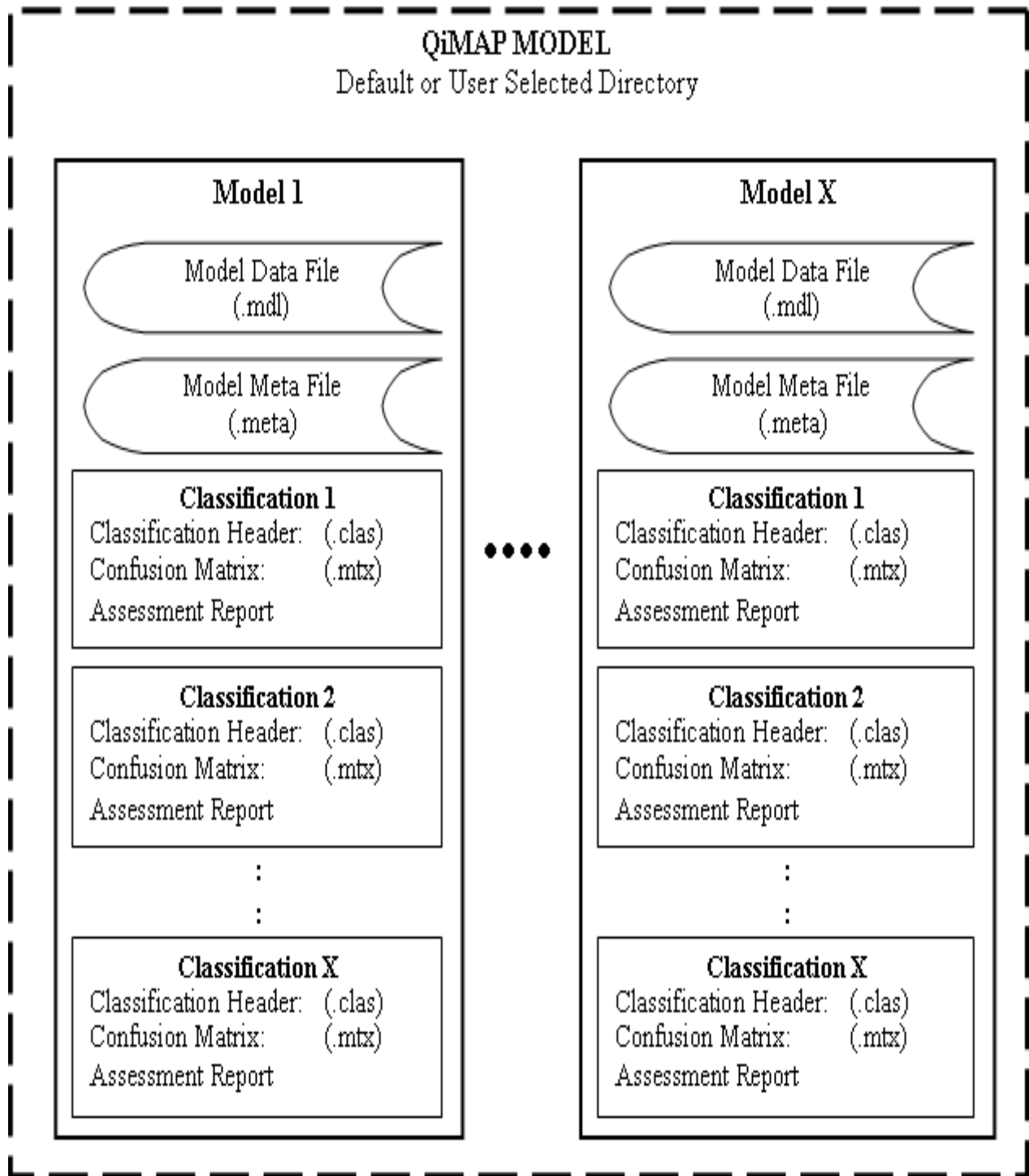


Fig 2: Quantitative Image Classification Accuracy Modeling and Assessment Program (QiMAP) Model Structure

5.6 Program Flowchart

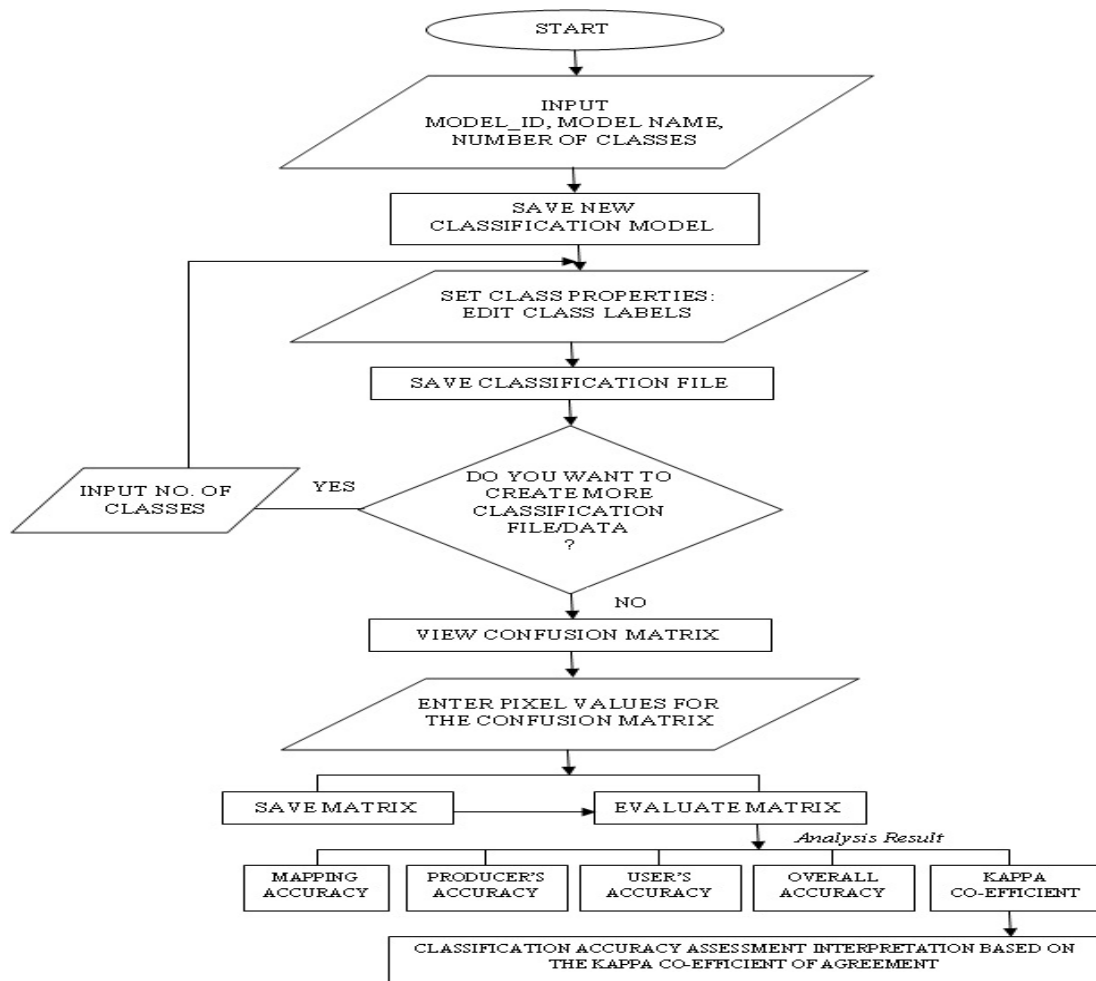


Fig 3: QiMAP Program Flowchart

Fig 2 describes the model structure used in the development of the Quantitative Image Classification Accuracy Modeling and Assessment Program. The model reveal a structure in which several classification models can be created and multiple classification files/data can be develop within each model. This is useful in comparative analysis of two or more classification exercises or data. The figure also describes the file structures used in building the software. The flowchart used in the implementation of QiMAP codes is described in Fig 3. The flowchart shows the necessary stages and processes of program execution used in QiMAP.

The Quantitative Image Classification Accuracy Modeling and Assessment Program (QiMAP) presented in this paper interpret the result generated from the evaluation of the confusion matrix based on the Kappa Co-efficient and uses the Landis and Kosh scheme of agreement (Table 1) to presents its final remark on the analyzed classification.

6. PROGRAM RESULTS

6.1 Evaluation of Classification Data

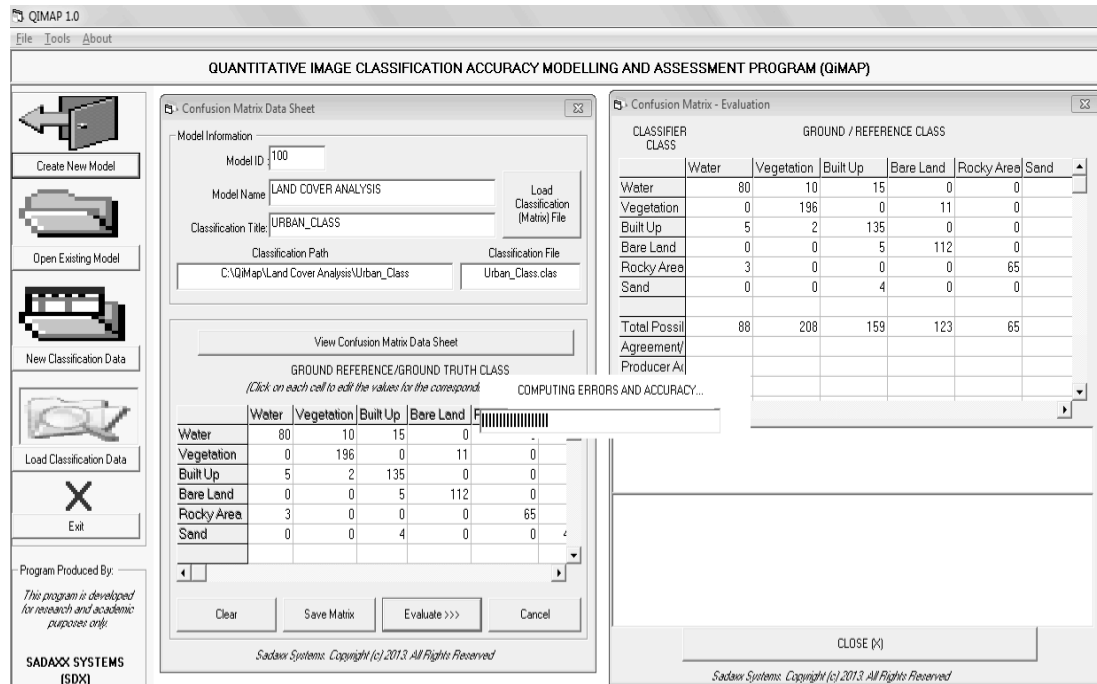


Fig 4: Classification Accuracy Assessment Result Interface and Processing

6.2 Accuracy Assessment Result and Interpretation

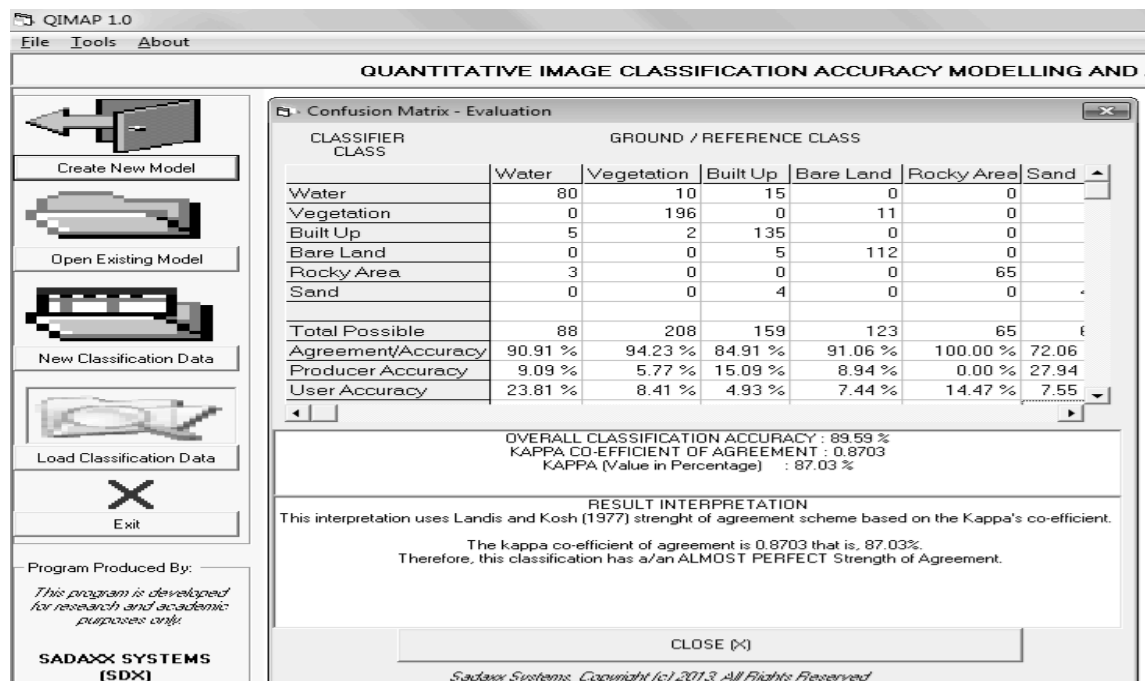


Fig 5: Accuracy Assessment Result and Interpretation

The preceding sections (Section 6.1 and 6.2) present selected interfaces (Figures 4 and 5) from QiMAP as used in the evaluation of the accuracy of the sample classification data. The data represent sample classification derived from the study on analysis of land use/land cover changes pattern along river Benue channel in Adamawa State, Nigeria.

The final accuracy assessment result (Fig 5) revealed that the overall accuracy of the classification illustrated is 89.59 % and the Kappa co-efficient of agreement is 0.8703, that is, 87%. The classification presented is deemed acceptable since the overall accuracy is above the commonly recommended level of 85%. Therefore, the classification was interpreted to have ALMOST PERFECT strength of agreement with the reference data (reality) based on the Kappa co-efficient of agreement of 0.8703 using Landis and Kosh (1977) scheme of agreement (Table 1).

7. CONCLUSION

This paper presented the development and application of the Quantitative Image Classification Accuracy Modeling and Assessment Program (QiMAP) for sustainable geospatial technology (remote sensing) applications. The program was used in the evaluation of classification accuracy of land use/land cover pattern analysis along river Benue channel in Adamawa state, Nigeria. The results of the classification accuracy assessment produced by the software include the Agreement/Accuracy, Overall Accuracy, Producers Accuracy, Users Accuracy, Mapping Accuracy, Kappa Co-efficient, and interpretation of the assessment using Landis and Kosh scheme of agreement based on Kappa.

Remote sensing images – which is the digital representation of reality has been largely analyzed and used in making crucial decisions in reality. Therefore, the quality of how it represents reality and accuracy of its classification into themes has significant impact on the efficiency and sustainability of decisions it is used for.

Assessment of image classification has widely been neglected. And where the accuracy is assessed, the qualitative method is generally adopted. Only few cases of researches and studies that involve image classification have been reported to use the quantitative method which is a more reliable method of accuracy assessment. In most cases, classification maps are arbitrarily overlaid on the reference map or vice versa. Any map with good visual impression is generally accepted has been accurate. However, there remains a great distinction between accuracy, validity and eligibility of a map. A map may be cartographically correct – using necessary symbolization and representations and yet not accurately represents the reality which it portrays. The quality and reliability of a map rely not only in its visual impression but also in how well it represents reality – accuracy. Quality of a map can only be ascertained if its accuracy is determined.

Many researchers and scientists often find it difficult to examine the accuracy of classification quantitatively due to the rigorous statistical and computational methods involved. Development of standard computer applications such as QiMAP eases the task of

accuracy assessment. This also encourage consideration for the assessment of the accuracy of image classification in various studies, researches and projects.

To ensure a reliable utilization of remote sensing data in making efficient decisions for both short term and long term sustainable benefits, image classification accuracy assessment is a step that should not be neglected or deemed optional but consider as a prerequisite for acceptability of any thematic map derived from remote sensing data analysis. To pursue this stand, development and use of standard applications such as QiMAP would accelerate the appraisal of accuracy assessment for image classification, hence, sustainable application of geospatial technologies – remote sensing.

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BIOGRAPHICAL NOTES

Mr. Adefioye Sunday Adewumi graduated from the Obafemi Awolowo University, Ile Ife, Nigeria with Bachelor of Science Degree in Geography. He earned a Diploma Degree in Computer Science and Technology from the same university and also took courses in computer programming and database management and administration. Among others, some of his published works includes;

1. Analysis of Land Use/Land Cover Pattern Along River Benue Channel in Adamawa State, Nigeria. (ref. ii)
2. Geospatial Analysis of Wetlands for Urban Agriculture in Ile Ife, Nigeria: Imperative for Sustainable Urbanization. Published in the Nigerian Geographical Association Journal. June 2012.

Adefioye is well recognized for the development and donation of *GeoTools version 1.0.0* (software he developed for geographic data management, coordinate transformation and basic

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geographic navigation) to reputable geospatial/space research centres and university in Nigeria.

Commendations

He has received formal commendations from centres and university such as;

1. Advanced Space Technology Applications Laboratory (ASTAL) – (NASRDA), Federal Ministry of Science and Technology, University of Uyo, Uyo, Nigeria – 29th July, 2013
2. The African Regional Centre for Space Science and Technology Education in English (ARCSSTEE) – affiliated to United Nations, OAU, Ile Ife Nigeria – 2nd July, 2012
3. Regional Centre for Training in Aerospace Surveys (RECTAS) – under the auspices of the United Nations Economic Commission for Africa (UNECA), OAU Campus, Ile Ife, Nigeria – 28th June, 2012, and
4. The Department of Geography, Obafemi Awolowo University, Ile Ife, Nigeria – 26th January, 2012

Award

He is one of the recipients of the Golden Jubilee Award of Excellence in Learning and Culture and as one of Distinguished Alumni of the Department of Geography, Obafemi Awolowo University, Ile Ife, Nigeria in November 2012.

Conference Presentations

Adefioye has authored and presented papers in notable national conferences in Nigeria. Among others, some of these presentations are;

1. Indigenous Geo-Software Development: Imperative for Sustainable Geo-spatial and Space Technology Development in Nigeria
2. Computing and Computer Programming for Geospatial Research and Applications in Nigeria

Software

He has also developed over 15 software packages for research and academic purposes, these includes;

1. Trends Surface Modeling and Analysis Program (SurfMAP)
2. Quantitative Image Classification Accuracy Modeling and Assessment Program
3. Integrated Data Relationship Modeling, Positioning and Transformation Software
4. SDX Batch Coordinates Transformation Software
5. GeoTools
6. GeoNav
7. Geo-Distance Calculator, and
8. Several coordinates transformation software packages

Adefioye Sunday A. is the Founder and Managing Director of Sadaxx Systems, a research and development (R&D) based software development and capacity building company in Ile Ife, Nigeria.

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