Journal of Forest Science
Vol. 24, No. 3, pp. 151~154, December 2008

Potential of the kNN Method for Estimation and Monitoring off-Reserve Forest Resources in Ghana

Christian Kutzer*
Department of Forest Biometry, Albert-Ludwigs-University Freiburg, Germany

ABSTRACT : Dramatic price increases of fossil fuels and the economic development of emerging nations accelerates the transformation of forest lands into monocultures, e.g. for biofuel production. On this account, cost efficient methods to enable the monitoring of land resources has become a vital ambition. The application of remote sensing techniques has become an integral part of forest attribute estimation and mapping. The aim of this study was to evaluate the potentials of the kNN method by combining terrestrial with remotely sensed data for the development of a pixel-based monitoring system for the small scaled mosaic of different land use types of the off-reserve forests of the Goaso forest district in Ghana, West Africa. For this reason, occurrence and distribution of land use types like cocoa and non-timber forest resources, such as bamboo and raphia palms, were estimated, applying the kNN method to ASTER satellite data. Averaged overall accuracies, ranging from 79% for plantain, to 83% for oil palms, were found for single-attribute classifications, whereas a multi-attribute approach showed overall accuracies of up to 70%. Values of k between 3 and 6 seem appropriate for mapping bamboo. Optimisation of spectral bands improves results considerably.

Keywords : K nearest neighbour, Combination, Terrestrial, Remote sensing, Estimation, Distribution, Non-timber forest product

INTRODUCTION

Like most tropical countries, the forest resources of Ghana are decreasing at alarming figures. Agricultural expansion has been identified as the common factor in deforestation. In many respects, degradation of Ghanaian's off-reserve forests indirectly increases pressure on forest reserves. About a third to two-thirds of the timber harvested annually in Ghana comes from off-reserve forests (Mayers et al., 1996). These lands outside forest reserves exhibit a mosaic of agricultural field, fallow lands, secondary forest patches, and settlements. It is of great significance if the condition of forestland is able to provide the variety of goods and services required from them. However, wise and prospective planning and management decisions on the level of stakeholders, local authorities and policy-makers can only be undertaken when adequate information on these land resources are available.

Forest inventories, based on classical terrestrial sampling are very time consuming and costly, particularly when carried out in the tropics. The development and adaptation of methodologies which combine terrestrially collected with remotely sensed information is a way out. The k-nearest neighbour algorithm (kNN) is a method for classifying objects based on closest training examples in the featured space. With the combination of terrestrial samples and satellite data through the application of the k-nearest neighbour method, forest inventories, detailed stand maps and image classifications have already been supported (Holmgren et al., 2000; Holmström, 2001; Gustafsson, 2002; Stümer, 2004; Tomppo, 2005). Originally, the method was developed for the derivation of maps for metrical data. Due to the fact that categorical data disallow average determination, the kNN method was extended to the application of categorical data (Köhl et al., 2000). The objective of this study is to evaluate the potential of the kNN

* Corresponding author: (E-mail) kutzer@biom.uni-freiburg.de
※ Advance in Forest Management and Inventory-selected papers from the international conference of IUFRO (Div. 4.01, 4.02, 4.04), Chuncheon, Korea, Oct. 13-17, 2008.

method applied as regards the combination of terrestrial with spectral data. It is the aim to estimate non-timber forest products and land resources, to inventory off-reserve tree and forest resources, to generate resource distribution maps, and to give guidelines and recommendations for a monitoring system.

METHODS

Study Area

The study area comprises the off-reserve forests of the forest district Goaso in Ghana, excluding all forest reserves and shelterbelts, and was pre-selected by the Tropenbos Ghana Project, into which this study is incorporated into (Tropenbos, 2007). The study area includes forest and agricultural sites of the Asunafo Administrative District of the Brong Ahafo Region of Ghana. It covers a total area of 2187.5 km^2, including 6 forest reserves with a total area of 779.4 km^2 (Tropenbos, 2007). The geographical position lies between latitudes 6° 27' North and 7° 00' North and longitudes 20° 23' West and 2° 52' West (Fig. 1).

Inventory Design

Based on a 7 by 7 km grid, samples of typical land use types (table 1) were selectively located, the geographic coordinates of the variable sample circle centres were acquired using a GPS receiver, and further information and characteristics on the vegetation were recorded:

- main land use type
- proportions of other land use types/intercropping, including shade trees
- average vegetation height
- radius of the variable circle plot (respectively crown diameter for individual giant trees)
- date of record
- extent of exploitation (only for bamboo)

Only sample plots with a circle radius of at least 15 m were selected. A buffer around each plot was generated dependent on the circle radius. Afterwards, each encircled pixel was exported with its geographic coordinates and the code for the registered main land use type (q.v. Kutzer, 2008).

ASTER Image

In this study an ungeoreferenced ASTER standard product level 1B was applied (ASTER, 2007). The image was taken on the 26th February, 2003. Out of 14 bands of

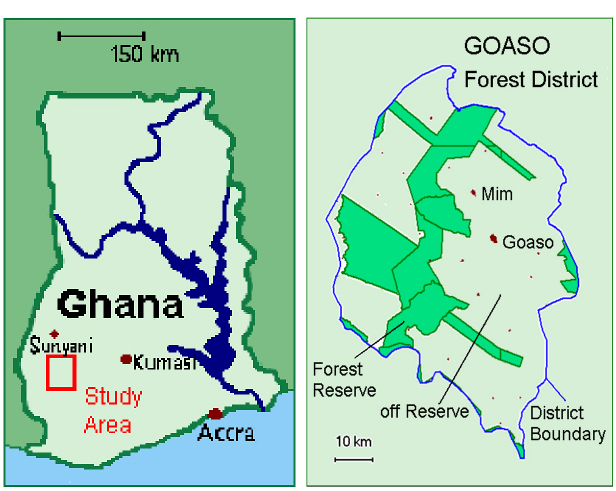

Fig. 1. The research site are the off-reserve forests of the Goaso forest district in the southwest of Ghana.

Table 1. Cypher code of the land use types and sample size for each class.

Land Use Type	Code	Sample Size
Bamboo	1	309
Banana/Plantain	2	325
Bush Fallow	3	600
Cocoa Plantation	4	573
Elephant Grass	5	111
Grassy Vegetation	6	171
Herbal Vegetation	7	319
Oil Palm Plantation	8	317
Raphia Palms	9	118
Trees/Forest	10	517
total		3360

the ASTER image, bands 1, 2, 3N, and 3B with a resolution of 15 m, and bands 4, 5, 6, 7, 8, and 9 with a resolution of 30 m were taken. For the geo-referencing separate basing points were collected and applied to the image geometric correction function. After geometric correction, 79% of the reviewed points showed a geometric error smaller than 5 m. The maximum error of 5-10 m was found for 6% of the tested points. Preliminary tests indicated that the classification accuracy of the kNN estimations increases with a higher number of applied bands, or, at least, by specific selection of band combinations. Additional bands were calculated out of the original ASTER bands, e.g. through mathematical combination or calculation of indices (e.g. vegetation index).

RESULTS AND DISCUSSION

A total of 3360 sample pixels distributed over ten different land use types encroached upon the kNN estimations. For the accuracy analyses, the sample pool was divided into two collectives. The training pixels are used as input data (ground truth) for the “training” of the kNN programme, whereas the accuracy of the kNN estimations is assessed with the control pixels and do have no influence on the current kNN estimation. Despite a selective sampling, due to individual distribution patterns and habitat areas, sample sizes varied within the different land use types (table 1).

For a singles-attribute classification (e.g. bamboo & non bamboo), the ten land use types exhibit different levels of overall accuracy for the various band combinations (Fig. 2). Oil palm plantations generally show higher accuracies over all band combinations, whereas banana was found at a lower level. With the optimisation of band combinations, accuracies could be increased for all classes. Overall accuracies were found up to 83% (averaged) for oil palms, while the bush fallows, banana plantations, and grassy areas define the lower end. Reasons might be the presence or absence of intercropping and the heterogeneity/homogeneity within specific land use types.

For the kNN estimations the programme developed by Stümer (2004) was used. This software allows to process up to 999 training pixels. An increase of sample size from 50 to 998 training pixels was simulated. With higher numbers of sample pixels, higher accuracies were found. For cocoa the overall accuracy could be increased from 69% for 50 pixels to 77% for 998 training pixels, with a peak of 83% for a sample size of 650 pixels. Sample sizes of 800 and more exhibit a lower standard deviation of the accuracies, approximately below 3%, whereas lower sample sizes show a higher variation of the repetitions, with a standard deviation of about 4.5%.

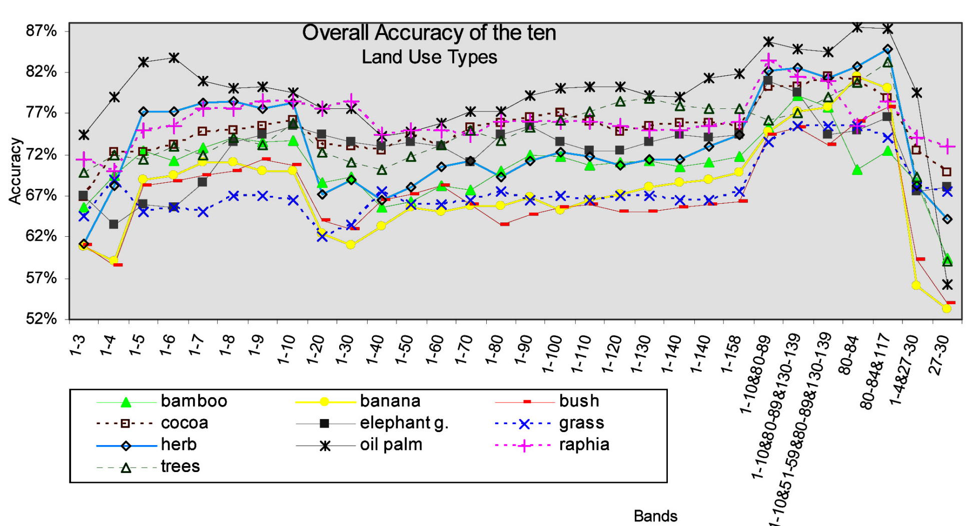

Fig. 2. Overall accuracy of the ten land use types calculated for specific groups of band combinations.

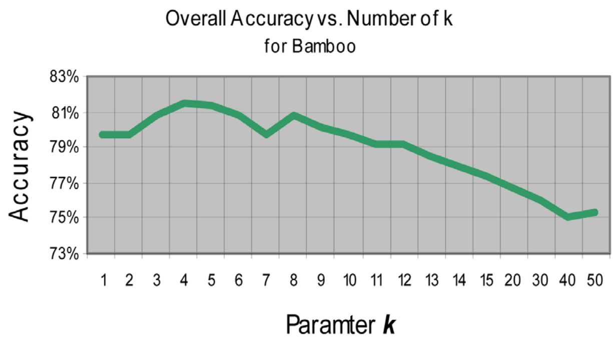

Fig. 3. Overall accuracy of the kNN estimations for bamboo and varying values for the parameter k.

Influencing the numbers of considered nearest neighbours, *k* is defined as the key variable of the kNN programme. Manipulating this parameter also allows to have influence on the classification results. In this study test series for bamboo showed an optimum value for k when selecting 4 or 5 neighbours for the estimations (Fig. 3).

Tests with multi-attribute classifications show an overall accuracy of 55%. By restricting classified pixels to an occurrence probability p of at least 0.5 instead of 0.2, an increase in accuracy to 70% was found. This happened on the cost of 42% of the pixels to be rejected due to failing the threshold of p = 0.2. These refused output pixels will not distribute to the resulting classification. Output pixels below the minimum occurrence probability have to be labelled as "unclassified" on the map.

CONCLUSIONS

Finally, the results of the study demonstrate a high potential for the application of the kNN method for a monitoring system of the land resources of Ghana's off-reserve forests. Advantage of the kNN method is its capability to cover the very small scaled mosaic of different land use types in Ghana's off-reserve forests. Adaptation of individual parameters, for instance the value for k, optimisation of spectral data, sample size and design applied to specific land resources, will further increase the expected estimation results and classification accuracies of this study. At this point, the estimation and inventory of non-timber forest products, in particular raphia palms, is limited to habitats bearing a specific minimum ground cover and exhibiting an agglomeration of individuals to be captured by the satellite sensor. For detailed estimation and inventory of bamboo and raphia, the proportions of land cover can be used to estimate quantities of NTFP resources. However, further studies on the correlation of stock quantities versus habitat cover are highly suggested.

LITERATURE CITED

Aster, G. D. S. 2007. ASTER GDS Web Site, Earth Remote Sensing Data Analysis Center. http://www.gds.aster.ersdac.or.jp/gds_www2002/index_e.html Accessed 08/22/2007

Gustafsson, K. 2002. Demonstration of methods to monitor sustainable forestry. EU/LIFE project 1998-2001, Rapport 8. Skogsstyrelsen, Jönköping.

Holmgren, J., Joyce, S., Nilsson, M., and H. Olsson. 2000. Estimating stem volume and basal area in forest compartments by combining satellite image data with field data. Scan. J. For. Res. 15: 103-111.

Holmström, H. 2001. Data acquisition for forestry planning by remote sensing based sample plot imputation. Doctoral Thesis, Swedish University of Agricultural Sciences, Umeå, 41 pp.

Köhl, M., Stümer, W., Scheuber, M., Ziese, H., Häussler, T., and M. Lautner. 2000. Combining hyperspectral data and ground surveys for the assessment of non-wood goods and services of forests. In: A Decade of Trans-European Remote Sensing Cooperation (Buchroithner, M. F.), Proceedings of the 20th EARSel Symposium, Balkema Publishers, Tokyo.

KUTZER, C. 2008. Potential of the kNN Method for Estimation and Monitoring off-Reserve Forest Resources in Ghana. Dissertation. Faculty of Forest and Environmental Sciences, Albert-Ludwigs-Universität Freiburg im Breisgau, Germany, 130 pp.

Mayers, J., Howard, C., Kotey, E. N. A., Prah, E., and M. Richards. 1996: Incentives for sustainable forest management: A study in Ghana. IIED Forestry and land use series No. 6. International Institute for Environment and Development, London.

Stümer, W. 2004. Kombination von terrestrischen Aufnahmen und Fernerkundungsdaten mit Hilfe der kNN methode zur Klassifizierung und Kartierung von Wäldern. Dissertation, Fakultät für Forst-, Geo- und Hydrowissenschaften, Technischen Universität Dresden, 153 pp.

Tomppo, E. 2005. The Finnish multi-source national forest inventory. In: Small area estimation and map production. Kangas, A. and Maltamo, M. (eds.). Forest inventory. Methodology and applications. Springer, Netherlands.

Tropenbos, 2007. Tropenbos International Ghana Programme. http://www.tropenbos.nl/sites/site_ghana.php Accessed 07/24/2007