Land vegetation ethiopia

1. Project Summary

Land cover/use Study projects provide policy makers, industry and community interest groups, and landholders with accurate information on woody vegetation cover, information on changes in the cover, mapping and providing statistical information.

In earlier times the northern Ethiopian highlands were characterized by humid climate and denser vegetation (Bard et al., 2000). Significant human impact on the land resource resulted in 65 per cent of the total land mass to be a dry land. Land clearing for agricultural activity has become an increasingly main topic in the natural resource debate that contrasts the economic aspects of land development to the people dependent on it and with the ecological need to conserve.

This project is a one of the initiative to investigate the land cover and its respective slope of the study site and to recommend technologies applicable to the overall land cover study projects in the dry high lands of Ethiopia.

The study combines field verification and computer processing using state-of-the-art remote sensing and Geographic Information System (GIS) technologies. The study specifically applies and eexplore the potential of Visible and Near Infrared (VNIR) bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer ASTER images to discriminate land use categories where the land is fragile with mixed uses villages, patches of forest, patches of grazing land, crop land, wasteland, etc. the study will also explore the potential of ASTER images to provide stereo images for DEM generation of the scene that can be used to generate the Slope. The DEM generation task will investigate developing a rational polynomial function model. At last integration of the land cover and the DEM together with other GIS data can be used as input data to classify the suitability of land for specific land use.

2. The Problem Statement and Justification for the Research

More than 63% of all smallholders in Ethiopia have less than 1 hectare of land. Population is growing rapidly and, although in the northern parts of the country the average rural population density is only 33 persons per square km, the population density per unit of arable land is much higher (138 persons per square km). Land fragmentation is common and the more fragmented holdings are, the more time it takes to manage them, with potential consequences for productivity. The national average is 3. 2 parcels per smallholder, though districts averages vary from a little over 1 to more than 5. The broadest areas of high fragmentation are in eastern Amhara and Tigray, although there are also districts with high average fragmentation in Gambella, parts of SNNP, and the eastern highlands. (Ethiopian Agricultural Sample Enumeration, 2001/02. Central Statistical Authority.). As a result of fragmentation, farm sizes are very small and the use of fallow is rapidly disappearing, causing problems of declining soil fertility and erosion.

Population growth increases the demand for land and contributes to farming on steep and fragile soils, also leading to erosion problems. It increases demand for biomass as a source of fuel, leading to deforestation and increased burning of dung and crop residues, thus increasing the problems of erosion and nutrient depletion. Population growth increases demand for livestock products and therefore leads to increased livestock numbers, causing overgrazing and consumption of crop residues by animals.

In such situation Land degradation is a great threat for the future and it requires great effort and resources to improve. The major causes of land degradation in Ethiopia are the rapid population increase, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production. Inappropriate land-use systems and land-tenure policies enhance desertification and loss of biodiversity. The balance between crop, livestock, and forest production is disturbed, and the farmer is forced to put more land into crop production.

The government has envisaged long- and short-term strategies to reduce the pressure on land and land fragmentation. Among the short term strategies are providing technical and vocational training to the landless youth to enable them to find off-farm employment and encouraging emigration to urban centers and to other parts of the region for resettlement. These strategies recommended allocation and reallocation of land to be based on the land use classification to be done in detail study.

Understanding the current status of land use is very important and this project will come up with important elements of current land use study using remote sensing technologies to provide reliable information that help to prepare a complete land use plan.

Justification

Land Cover/ Slope Study

To approach the growing problems of natural resource management, spatially explicit information about physical, biotic, and human factors must be available in a variety of geographic and temporal scales (USFWS 1976). Local planners and managers require detailed knowledge of the region for which they have responsibility as well as information on the regional, state, and national levels. Land cover data are essential at several scales.

Current land cover data are vital to many applications including: making basic habitat assessments, delineating specific vegetative communities, calculating soil loss, and evaluating water quantity/quality within and between watersheds. The list of categories to be mapped is determined through the objectives of the mapping effort. This thesis describes such a mapping effort, one of presenting a basic land cover/Slope map, along with methods useful for land use planning applications.

The conventional methods in producing DEMs need large campaigns that result in land surveying teams using analogue or analytical techniques. In the last decades satellite stereo image based topographical map production is turned into operational state from its experimental state. Recently many local scale landscape or topographical monitoring requirements are maintained by high resolution satellite images (Kanab 2002, Zomer et al. 2002, Baily et al. 2003, Su¨zen and Doyuran 2004a, b, Liu et al. 2004).

Advantages of ASTER for land evaluation

The ASTER sensor is carried on board the Terra satellite that was launched in December

1999. The sensor has 14 spectral bands; three for Very Near Infra Red (VNIR) at 15 meters resolution, six for Short Wave Infra Red at 30 meters resolution, five for Thermal Infra Red at ninety meters resolution. Graphic 1 (below) shows the band coverage of the ASTER sensor. Thus with such resolution and number of bands it is possible to discriminate small fragile lands typical of Ethiopian highlands.

In addition ASTER imagery has an extra channel of image data that is created by the sensor capturing a backwards looking image for the third VNIR band. So for image band three there exists one (nadir) image channel and also a backwards looking (off nadir) image channel. This creates an along-track stereo effect that provides DEM generation capability to be used for slope study.

Scope

This thesis presents a small watershed land cover/Slope map representing for the northern region of the country. It will provide information just beyond the local watershed by demonstrating feasibility of using selected satellite imagery for regional planning as well.

It is known that Land suitability analysis is the process of matching demand, crop requirement, and supply, the quality of the land. Where it is necessary to specify the type of specific land use (e. g for forest plantation, maize, rangeland, etc.) so as to match with crop requirement, basic land characteristics, such as depth of soil, climate, amount of pH, level of soil nutrient, depth to ground water, etc.. Thus the scope of this thesis is limited to generating parameters necessary for the land suitability analysis.

- Project Objectives

General objective

- To demonstrate the feasibility of Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) imagery to provide base line data for land use planning for sustainable land management

Specific objectives

- Investigating discriminating power of ASTER Imagery in studying land cover in highly fragmented high lands of northern Ethiopia.
- To develop rational polynomial function model to generate a DEM that will be further processed to develop slope information.

4. Description of Project Activities and Methodology

Selecting Study Area

The landscape of Ethiopia is extremely diverse. In order to map land cover on a regional scale, it is necessary to understand the structure and dynamics of land cover on a local scale. To this end, the study area will be located to approximately represent throughout the northern part of the region. Thus the site will include major physiographic regions, i. e., predominantly mountains, valleys, and plains. On top of that the study site will be chosen on the following criteria: ease of access to allow comparison of actual land cover to images in hand, availability of current digital cover maps, and representation of regional land cover.

Classification Scheme

The first step in land cover mapping is to determine a classification system, i. e., to list the land categories to be mapped. Several items will be considered in this process:

- The objectives
- The characteristics of the data
- And the accuracy requirements.

As in most well planned mapping efforts, the objectives determine the classes and the procedures used. Since the objective of this study is to identify fragmented land use types rather than classifying different vegetation types, emphasis will be placed on land impacted by human activities.

The data available also determined the level of detail. ASTER imagery is assumed to be the best data currently available. The relatively high spatial resolution and the number of spectral bands of this imagery offers the best opportunities for discriminating a variety of cover types among any available satellite data such as Landsat.

Imagery

ASTER imagery with 15m spatial resolution, which is taken in the dry season of 2003, is the basic dataset from which land cover and Slope will be mapped. The data to be used for land cover study will be the VNIR bands (Band 1: 0. 52-0. 60 Lm; Band 2: 0. 63-0. 69Lm and Band 3N: 0. 76-0. 86Lm) of and 3N and 3B bands for the Slope study. A DEM created from ASTER level 1A (L1A) imagery can be expected to have a vertical accuracy of approximately 25 meters. Although in areas with less vegetation or man made features, this can rise to approximately 11 meters. It is therefore useful for small to medium scale mapping applications, 1: 50, 000 to 1: 100, 000.

Only the near-infrared (NIR) channel of ASTER image has stereoscopic view capability as another NIR sensor is located as back view on board Terra satellite. Therefore, one NIR sensor collects image in nadir direction while another NIR sensor gets image in back-looking direction. Using two different looking directions, stereo imaging and DEM generation can be attained (Welch et al. 1998, Toutin 2002, Hirano et al. 2003).

Training Data for image classification

Since this study applies supervised classification, training data are needed at the start of classification. To this effect training data will be acquired from a variety of sources such as available maps, aerial photography of the same year and expert knowledge and review.

Image Classification

One scene for the land cover study and another nadir scene for the Slope study will be used for classification. To georeference the image, Ground Control Points (GCPs) will be collected from easily identifiable points using Geographic Positioning System (GPS). Image classification will be done either using pixel based supervised image classification or with object-oriented image classification depending on the accuracy to be achieved.

ILWIS 3. 3 software format will be the major image processing tools that will be used.

Ground Truth and Classification Accuracy Assessment

Before a map should be used, it is necessary to know its accuracy (Congalton1996). Accuracy assessment will be made using ground truth points to be collected from the major land use/cover types using GPS. It is recommended to have a ground truth at the same time of data acquisition, or at least within the time that the environmental condition does not change. A general rule of thumb is 75 to 100 reference points per category for a large image (Congalton 1996). However; for such a small scale study quite less number of reference points will be feasible.

Statistics

The Confusion Matrix

In order to determine the errors in the classification, the following model called c *onfusion matrix* : (IDRISI module CONFUSE.) will be applied where:

Matrix columns = ground data (assumed ‘ correct’)

Matrix rows = map data (classified by the automatic procedure)

Cells of the matrix = count of the number of observations for each (ground, map) combination

Diagonal elements = agreement between ground and map; ideal is a matrix with all zero off-diagonals

Errors of omission (map producer's accuracy) = incorrect in column / total in column. Measures how well the map maker was able to represent the ground features.

Errors of commission (map user's accuracy) = incorrect in row / total in row. Measures how likely the map user is to encounter correct information while using the map.

Overall map accuracy = total on diagonal / grand total

Statistical test of the classification accuracy for the whole map or individual cells is possible using the *kappa* index of agreement www. sc. chula. ac. th/courseware/2309507/lec_content. htm).

User's and producer's accuracy measure the correctness of each category with respect to errors of commission and omission. Accuracy of each class cannot be completely stated in one statistic; both accuracies are needed for a valid assessment.

User's accuracy is obtained by dividing the number correctly classified by the total number of pixels, within the classified image, of that class assessed. A low user's accuracy represents a high error of commission.

Producer's accuracy is calculated by dividing the number of pixels correctly classified by the total number of reference points within that class (bottom row of error matrix). A low

Producer’s accuracy represents a high error of omission. The Kappa statistic describes the degree of superiority (expressed as a proportion), that the classification results have as compared to a random classification.

DEM Generation

Developments in computers, broadening of visualization applications and the availability of geospatial data, made the use of digital elevation models (DEM) an indispensable quantitative environmental variable in most of the research topics.

The landscape change and process-based studies in digital Earth sciences require the excessive use of DEM (Ka¨a¨b 2002, Zomer et al. 2002, Baily et al. 2003, Su¨zen and Doyuran 2004a, b, Liu et al. 2004), for landslide susceptibility/hazard assessment, erosion susceptibility, glacier monitoring, geomorphological mapping, etc., in order to quantitatively represent or to analyse the morphology or the landscape.

Within this study, the major steps that will be performed are (1) pre-processing and (2)

The first step in pre-processing is the orthorectification of raw L1A images. The whole scene ASTER L1A image will be orthorectified using available 1: 50, 000 scaled topographic maps.

DEM generation from stereoscopic imagery is dependent on establishing the mathematical model relating the scene coordinates of conjugate points to the ground coordinates of the corresponding object point. Either rigorous or approximate models can be used to establish such a relationship. Rigorous modeling necessitates a full understanding of the imaging geometry associated with the involved sensor. Moreover, it involves the external characteristics (as represented by the Exterior Orientation Parameters – EOP) and the internal characteristics (as represented by the Interior Orientation Parameters – IOP) of the imaging sensor. Such characteristics are derived with the help of control information, which might take the form of a calibration test field, ground control points, and/or onboard navigation units (e. g., GPS/INS). However, the derivation of these parameters might not be always possible due to: the lack of sufficient control; weak imaging geometry (especially for satellite imaging systems with narrow angular field of view); and/or intentional concealment by the data provider (e. g., Space Imaging does not release the IOP and the EOP for their commercially available imagery). Therefore, there has been an increasing interest to investigate approximate models, which do not explicitly involve the internal and external characteristics of the imaging system. (A. Habib, E. M. Kim, M. Morgan, I. Couloigne, 2005).

There has been an increasing interest within the photogrammetric community to adopt approximate models since they require neither a comprehensive understanding of the imaging geometry nor the internal and external characteristics of the imaging sensor. Approximate models include Direct Linear Transformation (DLT), self-calibrating DLT (SDLT), Rational Function Model (RFM), and parallel projection (Vozikis et al., 2003; Fraser, 2000; OGC, 1999; Ono et al., 1999; Wang, 1999; Gupta et al., 1997; El-Manadili and Novak, 1996).

This thesis will apply RPF; it is based on the ratios of polynomials with different degree which can vary from 1 to 3. The coefficients are estimated using a large number of Ground Control Points (GCPs).

In general, the procedure for DEM generation from stereoscopic views can be summarized as follows (Shin et al., 2003):

• Feature selection in one of the scenes of a stereo-pair: Selected features should correspond to an interesting phenomenon in the scene and/or the object space.

• Identification of the conjugate feature in the other scene: This problem is known as the matching/correspondence problem within the photogrammetric and computer vision communities.

• Intersection procedure: Matched points in the stereo-scenes undergo an intersection procedure to produce the ground coordinates of corresponding object points. The intersection process involves the mathematical model relating the scene and ground coordinates.

• Point densification: High density elevation data is generated within the area under consideration through an interpolation in-between the derived points in the previous step.

The image orientation with rational polynomial functions involves general transformation to describe the relationship between image and ground coordinates. They provide a generic representation of the camera object-image geometry.

The RPF provided with the high resolution satellite images connect image space and object space by:

Row *or column* = *rpf* (λ, ϕ, *h*)

Where row/column is the image coordinates and λ, ϕ, and h are longitude, latitude and ellipsoidal height in geographic coordinates of WGS84 datum (Grodecki et al., 2004).

Direct solutions use rational function coefficients and sensor parameters information without any control points and refinement the original coefficients. Indirect solutions use ground control points for computing coefficients without using sensor parameters (Tao, Hu 2001).

Our solution is based on ground control points without any initial values of coefficients. First approximate values of parameters extract and then precise values compute with using ground control points. Rational Function Model with 20 parameters (Valadan, Sadeghiam 2002) is used in this paper as follow:

Where

: are the normalized row and column of pixel in image.

: are the normalized coordinates of the image point in the Conventional Terrestrial (CT) coordinate system.

: Rational Function Coefficients (RFCs).

Estimating the RFM coefficients

The method by which the RFM coefficients are recovered depends on the availability of a physical sensor model. In cases where a physical model is provided a terrain independent scheme can be applied. This scheme is based on the generation of a 3D grid in object space, using the physical sensor model. The 3D grid should contain several layers of points and its characteristics are determined by the coverage of the image and the terrain relief differences. Then, a Least Squares solution of the RFM coefficients can be derived. Finally, an estimation of the quality of the derived RFM coefficients should be carried out based on an evaluation of the residuals in a higher density 3D grid.

When a physical model is not available, a terrain dependent scheme is used. As in this scheme it is not possible to generate a 3D grid, the solution is highly sensitive to the terrain relief, as well as to the distribution, number, and quality of the GCPs used.

Generation

The generation process involves four steps: primitive extraction, primitive matching, space intersection, and interpolation.

Primitive extraction: At this stage, a decision has to be made regarding the primitives to be matched in the normalized scenes. Possible matching primitives include distinct points, linear features, and/or homogeneous regions. The choice of the matching primitives is crucial for ensuring the utmost reliability of the outcome from the DEM generation process. In this research, point features are chosen.

Förstner interest operator (Förstner, 1986) will be used to extract distinct points from the imagery. The operator identifies points with unique grey value distribution at their vicinity (e. g., corner points). The next section discusses the matching procedure of these points.

Primitive Matching: The matching criteria deal with establishing a quantitative measure that describes the degree of similarity between a template in the left scene and a matching window, of the same size, within the search space in the right scene. Either correlation coefficient or least squares matching could be used to derive such a similarity measure

Space Intersection: Following the matching process, conjugate points undergo an intersection procedure to derive the ground coordinates of the corresponding object points. The RPF equation will be used for such computation.

Interpolation: So far, the ground coordinates of matched interest points, which passed the consistency check, are derived through space intersection. These points are irregularly distributed and are not dense enough to represent the object space. Therefore, they need to be interpolated. In this research, Kriging will be used to interpolate the resulting object space points into regular grid. The Kriging methodology derives an estimate of the elevation at a given point as a weighted average of the heights at neighboring points.

5. Project Milestones and Expected outputs

5. 1. Expected output

Following are the expected outputs from this research;

Based on the success of ASTER imagery in demonstrating land cover classification and slope generation, the result herein may be used as basic data to assist slope management, land use planning, and other land management efforts such as land suitability, and landslide susceptibility mapping when combined with other GIS data.

Provides a procedure based on the rational polynomial function model for generating DEM directly from a stereo ASTER images, and other experimental results.

In particular, the method can be quickly and easily applied to areas with little map data, and at low cost.

Based on the success it can be extended for all the northern high lands of Ethiopia.

5. 2. Dissemination plan

The immediate users of the research result are policy makers, teaching institutes and other planning and development organization in their programming of land use management. It will also assist the local government in the design and making of policy issues. The small holder farmers are the ultimate users of the research results through well designed land management projects that are effective in ensuring sustainable development of the resources they are dependent on.

6. Work Plan

7. References

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