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Table of Contents

We resolve … to intensify our collective efforts
for the management, conservation and
sustainable development of all types of forests

United Nations Millennium Declaration, 2000

Preface

Applied Geoinformatics for Society and Environment (AGSE) series of conferences and summer workshops started in 2008 in Trivandrum, initiated by the initiavtives of Dr. Pradeepkumar (University of Kerla) and of the Alumni Representative of Stuttgart University of Applied Sciences, Prof. Dr. Franz-Josef Behr. After the successful follow-up conferences in Stuttgart (2009), Arequipa (2010), Nairobi (2011), back in Asia (Johor Bahru, Malaysia, 2012, and Ahmedabad, India, 2013).

The objective of the conference is to 'take the benefits of geographic information technologies to a wide canvas of applicable areas, particularly in the realms of development, environment and social well-being'. Since 2008 we – scientists, practioners, students, alumni – continue this path to empower one another in a participative way.

I wish this event a successful exchange of knowledge crossing borders and disciplaines.

Prof. Dr. Franz-Josef Behr

– Alumni Representative –

05 November 2014

Automatic Large Scale Topographical Map Updating using Open Street Map (OSM) Data within NoSQL Database Platform

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KEY WORDS: Topographical, Signature, Crowd-sourcing, Updating

ABSTRACT:

Basically there are two major important aspects of topographical maps, which can be considered as key performance indicators: geometric quality and up-to-datedness' of the map. In this context, adequate map updating is of special interest to achieve effective and efficient geospatial data provision over time. Crowd-sourcing information can potentially also be used for the map updating purpose because of its public participatory manner and its dynamic growth in terms of data volume and schema.

As a matter of fact, each dataset has its own features and structures depending on its geospatial data originator with their own technical specifications. Open Street Map (OSM) uses tags as a reference for feature identification in which users can modify or even create their own definition. In this case, the geospatial feature definition or conversion among different datasets is considered as a crucial stage.

NoSQL database technology has been introduced as a potential alternative solution to existing SQL databases which is supposed to grow more rapidly in the near future. It has the perspective to combine the powerful capability of GIS data processing with an approach of non-relational Data Base Management System (DBMS). This type of data warehouse can potentially accommodate variety of information over the World Wide Web (www) space with different structures into one single geodatabase. MongoDB as one instance of NoSQL database introduces an open source document storage empowered by a replication using a data partitioning approach across multiple machines.

This paper discusses the role of geospatial signatures for topographical object recognition from different vector datasets in an automated way. Its characteristic can be used to identify common objects i.e. points which subsequently play a role in geometrically transforming OSM data into official Large Scale Topographical Map. Hence, the proposed approach for an automation process concentrates on three steps, namely geospatial signature identification, transformation and finally vector data integration. The implementation of this approach is currently ongoing using Python scripting environment in the ArcGIS platform.

1 Introduction

1.1 Background

Topographic map data can be considered as essential and fundamental because of its high importance not only for the planning purpose but also for the evaluation of the ongoing infrastructure development such as road, building, utilities, etc. This basic type of geospatial data consists of natural and manmade objects which can be created with straightforward interpretation in the feature object classification e.g. land cover, geographical names. In other words, the uncertainty

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for feature identification within the topographical themes is considered not significant. As an example, land cover theme has to classify the general land object type such as forest, settlement, paddy field. It is not necessary to classify each specific type of forests in topographical map production. However, topographical maps include also 3D terrain information i.e. Digital Elevation Model (DEM). According to experience, the provision of DEM requires higher efforts compared to planimetric features such as roads, buildings, administrative boundaries, etc.

In particular for large scale topographical mapping, special emphasis is put on the update of maps of urban regions. This is specifically the case for third world countries, which can allocate only a limited budget to map production and update. Therefore, they concentrate on urban and dense populated areas. On the other hand, public participatory of geospatial communities over the internet can provide tremendous results within the context of crowd-sourcing activities. The main reason for this is the legal and physical openness in geospatial data sources which shares the attractive high resolution imageries as well as vector data sources. Open access geo-information has been widely used as the alternative technical reference for disaster preparedness and emergency response in rapid mapping activities (Tampubolon, 2012). It requires a frequent and dynamic update process to provide recent and actual geospatial data sets, especially during emergency situations. As the demand of geospatial dataset in post disaster i.e. reconstruction phase is increasing, the update mechanism for large scale topographical maps which include detail infrastructure features such as road network must be defined at the first place.

In the era of big geospatial dataset utilization nowadays, there are some prominent data aspects involved namely dynamic structure, high volume, and multi sources. Those aspects require a processing platform which can support real time geospatial data integration among different geospatial data sources over time. NoSQL databases introduce a new approach to overcome the problem of data structure inconsistency as a challenge to the conventional Relational Data Base Management System (RDBMS). The most important factors that trigger NoSQL technologies were the uprising of crowdsourcing and technology driven demands (Harrison, 2013).

MongodDB as an instance of NoSQL database implements schema flexibility by using Java Script Object Notion (JSON) format and a document based approach (Mongodb, 2014). Actually those two approaches will combine the advantages of flexible data structure and data transfer capabilities.

1.2 Research Objectives

The objectives of this research can be divided into three major parts as follows:

- Development of algorithm to recognize topographical object changes using GIS approach within NoSQL database platform;
- Development of an Automatic Large Scale Topographic Map (LSTM) updating mechanism by using ESRI platform i.e. Arctoolbox based on Python scripting environment;
- Technical implementation using Open Street Map (OSM) data to update LSTM road network dataset.

1.3 Technical Workflow

This research is conducted by combining theoretical and empirical approaches in order to achieve proper geospatial data quality in the context of large scale topographical map updating. Initially, the official large scale topographical map dataset has been selected as the benchmark for performing geospatial data assessment (Figure 1).

Using GIS data as a priori information has already been implemented in the map updating process (Bailloeul, 2003). It is assumed at this point that a topographical map is considered to be more accurate and complete in a comparison with other geospatial data sources. Therefore it has been used as a reference in updating purposes for both, the geometrical accuracy and the thematic correctness.

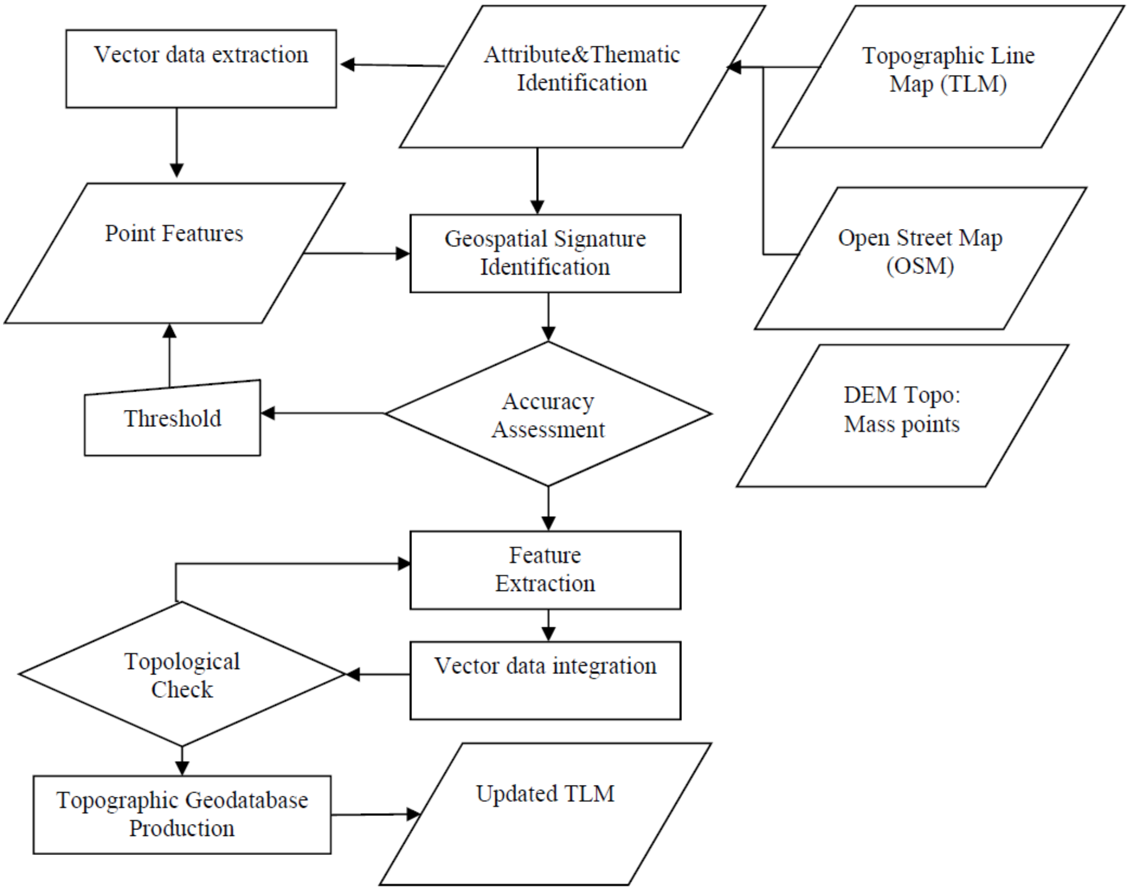

Figure 1: Algorithm workflow.

2 Map Updating Concept

The update mechanism used in this research comprises two major parts as described in the following. The first part has a close connection to the thematic and feature classification of geospatial datasets while the second part deals with the geometrical aspect.

2.1 Thematical update

OSM uses a free tagging system that allows participants to include any unlimited number of attributes for describing their feature interpretations. However, there are some agreements on certain fields, keys and values especially for the mostly used definitions and their combinations. This informal rule plays an important role to establish such a standard for creating geospatial data.

Nevertheless, users can define new features to improve the cartographic style of the map or to contribute on unmapped attributes of the features. In this case, short descriptions of each tag that relate to particular themes or interests can be provided using the feature pages as the reference.

Thematic aspects define the information content within a geospatial data set in which it can describe attribute fields including semantic aspects of the features. NoSQL databases offer advantages for this task e.g. by its schema flexibility and can therefore play a major role in future.

2.2 Geometrical update

Geometrical update has a strong connection with the newly created form of features in the real world. Although the spatial resolution of Very High Resolution Satellite imageries i.e. used by OSM is increasing, it does not always guarantee the geometrical accuracy as expected. In this case, it is necessary to assess geometrical accuracy of OSM data at the first place. Within the proposed approach it has to be considered also detect geometrical changes of topographical features.

Since different technologies provide various types of geospatial data quality, geometrical analysis will focus on self-assessment process to provide partial geometric accuracy for each dataset. Each single assessment will be subsequently combined with other assessments in order to identify geospatial relationships among them.

3 Technical Implementation

In order to detect changes, it is important to define criteria and mechanism with a logical argument as a reference. There are two approaches implemented for this purpose. The first part is how to define geospatial signature which shall be unique for each geospatial object. The second part focuses on quality measurement for the whole map updating mechanism scheme.

3.1 Geospatial signature identification

Change detection in this paper has a main objective for automatic feature distinction based on geospatial aspects. The term geospatial signature focuses on quantifying object identification using GIS approach as a tool. This tool operates regional based calculation by combining different datasets comparison.

$$G_{sign}(dX, dY) = (\sum_{n=1}^{m}(dist * \sin \propto), \sum_{n=1}^{m}(dist * \cos \propto)) \quad (1)$$

$$Dev_{sign}(dX, dY) = (\min_m \sqrt{dX^2 + dY^2}) \quad (2)$$

Where m = the number of points within regional based approach

- dist = distance from each point to the analyzed point
- α = azimuthal angle from analyzed point to each point
- dX = deviation in X axis
- dY = deviation in Y axis

Single assessment process for each dataset uses equation (1) to calculate point-based inter connection using angle and distance as the arguments. This calculation is followed by measuring minimum mean value for each point-based moving region as inferred from equation (2). In this case, the minimum mean value exposes common objects while maximum mean value gives different objects. By using this approach, updated features i.e. road segment (in yellow) can be detected as shown in Figure 2, in which maximum mean value exceeds geospatial signature threshold (G.Sig = 0.754).

Figure 2: Geospatial signature identification

3.2 Accuracy Assessment

The tolerances for accuracy assessment used here have been developed based on the National Mapping Accuracy Standard (NMAS), the horizontal tolerance accuracy can be seen in Table 1 (FGDC, 1998).

Map Scale	Tolerance at Publication Scale	Tolerance at Ground Distance
1:1,000	1/30 inch = 0.85 mm	0.85 m
1:5,000	1/30 inch = 0.85 mm	4.25 m
1:10,000	1/30 inch = 0.85 mm	8.5 m
1:25,000	1/50 inch = 0.5 mm	12.5 m
1:50,000	1/50 inch = 0.5 mm	25m

Table 1: NMAS Horizontal Accuracy Tolerance

4 Vector data integration

After the updated objects have been recognized, the planimetric (2 D) compilation can be implemented for updating the official Topographical Map Technical Specification in 1:5,000 map scale produced by BIG. This mechanism has provided ArcToolbox package in which it can directly utilize Mongodb documents storage to perform statistical analysis for geospatial signature identification purpose (Figure 3).

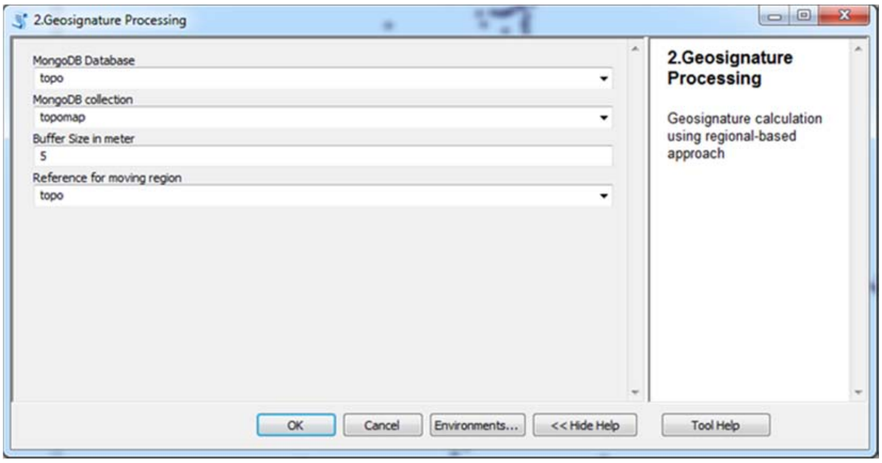

Figure 3: Python toolbox using arcpy.

5 Closing Statement

5.1 Conclusion

Finally this research has introduced the large scale topographical mapping updating mechanism by utilizing NoSQL database both as the GIS processing unit and the geospatial data warehouse. The accuracy of OSM data can be detected automatically in order to fulfill the large scale topographical mapping requirements.

Region-based approach is still considered as the best solution to identify geospatial signature both for geospatial data accuracy measurements and updated object detection. Algorithm created in this paper recognizes identical features and updated features for different purposes. The first is to measure geometric accuracy and subsequently the latter is to detect updated features in the automated way.

5.2 Recommendation

For the future works, in order to improve the challenging task for automatic large scale mapping updating, it is recommended to proceed with the following tasks:

Further algorithm development not only for accuracy assessment but also for OSM data transformation into official large scale topographical maps data.

Extension of geospatial signature identification approach for other purposes e.g. Ground Control Point (GCP) detection between different datasets.

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A Comparative Study on the Modeling Of Rainfall Pattern Using Kriging and Artificial Neural Network

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KEY WORDS: GIS, Kriging, Artificial Neural Network (ANN), Precipitation, Rainfall prediction

ABSTRACT:

Study of rainfall pattern is very crucial for water resource, environment, ecology, climatology as well as various other related fields. Many spatial methods are available for predicting rainfall pattern by interpolating historical mean rainfall from available precipitation stations. Kriging is one of the widely used deterministic and stochastic weighting methods in this field. This study involves modeling of rainfall pattern with Kriging and Artificial Neural Network, a data driven approach to acknowledge the spatial factors affecting rainfall in the Island of O'ahu in Hawaiian territory. Mean monthly precipitation data of 250 rainfall stations of O'ahu is collected for the month of October. 170 stations are used for training ANN model and creating Kriging surface; and rest 80 stations are used for testing the trained ANN model and developed Kriging surface. The performance of ANN model shows good fit (RMSE=40.99, R2=0.87) and very comparable to the performance of Kriging (RMSE=28.75, R2=0.92). The ANN model indicates that the rainfall pattern of O'ahu in October varies with spatial parameters- latitude, longitude and elevation. The performance of ANN model is very encouraging comparing the Kriging model and can be used as an alternative spatial interpolator for precipitation.

1 Introduction

Knowledge of the mean rainfall pattern is critically important for a variety of resource management issues including groundwater , surface water development and protection, controlling and eradicating evasive species, protecting and restoring native ecosystems as wel as planning for the effects of global warming (Giambelluca et al., 2013). Developing a mean rainfall pattern raster or contour involves collection of rainfall data from available rainfall stations for the Area of Interrest (AOI). Often there are sparse rainfall stations for the study area and it is difficult to produce an interpolated mean rainfall pattern raster for these sparse rainfall stations zone. Many different spatial interpolation models are available for rainfall pattern recognition prediction in ungauged areas; some are deterministic, some are stochastic and data driven. ASCE (1996) recommends normal ratio and inverse distance weighting methods for estimation of missing rainfall data. However, Kriging is one of the widely used deterministic and stochastic spatial interpolation techniques nowadays. Many researchers used it for rainfall data estimation at missing rainfall stations. Kriging has the ability to develop a spatial relationship between available data points along with a probability surface to judge the prediction at different location on the Kriging surface. Kriging is proved be accurate than other traditional spatial interpolation techniques like Thiessen polygon method, inverse distance weighting (IDW) method, multiquadric interpolation method, optimal interpolation method, spline method, nearest neighbor method etc. for rainfall interpolation at ungauged locations. Ashraf et al. (1997) used inverse distance method, square inverse distance method and Kriging to interpolate for missing rainfall data. They found lowest root mean square error (RMSE) for Kriging interpolation.

It is evident that data driven model like ANN sometimes may provide more significant rainfall pattern than deterministic method like Kriging. This study compares the rainfall pattern prediction using Kriging and ANN having focus on the apllicability of such models in terms of spatial context.

2 Study area and datasets

One of the Hawaiian Islands, the island of O'ahu, is considered as the study area of this research. The Hawaiian Islands are considered to have one of the most diverse rainfall patterns of the world. The mountainous terrain, persistent trade winds, heating and cooling of the land, and the regular presence of a stable atmospheric layer at an elevation of around 7,000 ft. interact to produce areas of uplift in distinct spatial patterns anchored to the topography (Giambelluca et al., 2013). There are dramatic differences in mean rainfall over short distance due to this uplift and resulting cloud. The rainfall atlas of Hawaii is already developed; it represents annual mean rainfall and also every months mean rainfall. Rainfall data was collected for the 30 years base period 1978-2007.

In this study the mean monthly rainfall data for each rainfall station of the O'ahu Island is directly downloaded from the website. Stations shape file is also available in the site. Other hydrographic data is downloaded from USGS. For study purpose, the research is confined only to the monthly rainfall data of October; hence this research is focused on spatial distribution of rainfall, not temporal change.

3 Methods

3.1 Kriging Method (KEM)

For estimation of missing rainfall, several traditional weighting and data-driven methods are available. Inverse distance (Simanton and Osborn, 1980; Wei and McGuinness, 1973) is only a weighting approach; whereas Kriging is a non-linear, deterministic and stochastic approach. The weights of the known points are directly related to the spatial correlation structure referred as semi-variogram. The weighted sum of the observations is assumed to provide the best estimate. Thus kriging is a method of determining the optimal weights. The semi variogram inside kriging describes the variance over a distance or lag h. Weights are adjusted according to the spatial arrangements of the sample points. The linear combination of weights is given by the following expression:

$$Y_i = \sum \lambda_i \, y_i \qquad (1)$$

where Y_i is the Kriging estimate, y_i is the variables evaluated in the in the observed locations and ${}_i$ is Kriging weights.

The general expression to estimate the semi-variogram is given by

$$\gamma(d) = \frac{1}{2n(d)} \sum_{dij=d} (y_i - y_j)^2 \qquad (2)$$

where (d) is the semi-variance defined over observations y_i and y_j; which are lagged successively by distance d.

Kriging output depends on the semi-variogram model used in the study. Several mathematical models are available to produce a semi-variogram include linear, spherical, circular, expotential and Gaussian.

A typical spherical semi-variogram is shown in Fig. 1.

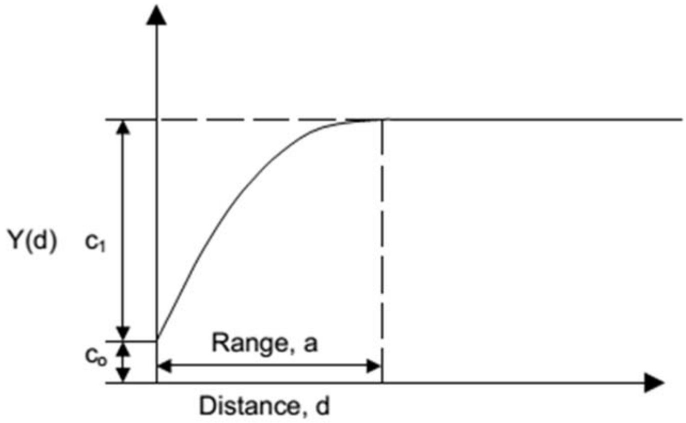

Figure 1: Typical spherical semi-variogram.

In Fig. 1, the parameters,C_0, d and a are referred to as nugget, distance and range respectively. The summation of C_0 and C_1 is referred to as sill and the semi-variance at range, a, is equal to the sill value.

Details on Kriging can be found in Tabios & Salas (1985).

3.2 Artificial Neural Networks (ANN)

Artificial neural network (ANN) is a flexible mathematical model that can identify and simulate complex nonlinear relationship between inputs and outputs. It have been applied extensively in the past decade in the field of hydrology for estimation and forecasting of hydrological variables (ASCE, 2001a,b). The main difference between various ANN's are arrangement of neurodes (network architechture) and different ways to determine weights (w) and functions for inputs (x) and neurodes.

In a typical ANN architechture (Fig.2), the network receives some inputs (x) to calculate the weighted average (z) using weights (w). Then use some transfer function (f) to produce the output.

$$Z = \sum_{i=1}^{n} x_i w_i \qquad (3)$$

The input and hidden layers are connected by the weights (Eq. (3)). Weights are determined through training or learning of the system. The hidden layers take weighted inputs to produce the output using a transfer function. The transfer function is often referred as activation function. For practical interest, most ANN uses sigmoid functions; since it enables a network to map any nonlinear process (Bishop, 1994; ASCE Task Committee, 2000). It gives values between 0 to 1 when the input (x) varies. Many mathematical functions can qualify as a Sigmoid function (f(z)). A typical one is given below:

$$f(z) = \frac{1}{(1 + e^{-z})} \qquad (4)$$

In the current study, ANN method is used for estimation of missing rainfall values to produce a rainfall pattern raster. The architecture of the developed ANN model in the current study is given in Fig. 2. The architecture is a feed-forward network, consists of one hidden layer with three hidden layer neurons. To develop the ANN model, ANN MOGA-XL tool is used (Giustolisi and Simeone, 2006). The hidden layer neurons are selected based on model performance in testing data. For training, tan-sigmoid function is used as activation function.

3.3 Model Architecture

Precipitation depends on many factors; initially all the plausible variables effecting precipitation are taken into account. Eventually the contributing inputs inputs for spatial variability of precipitation are sorted out by the ANN model. The following variables are chosen as inputs: longitude of the station (X), latitude of the station (Y), elevation of the station (E), land slope of the station (S), land cover surrounding the station (L), distance to nearest waterbody (Dw), distance to nearest known precipitation station (DP) and mean monthly precipitation of the nearest station (P').

The inputs are normalized with values ranging between 0.01 to 1 using the following equation:

$$X_n = \frac{0.99(X_i - X_{\min})}{(X_{max} - X_{\min})} + 0.01 \quad (5)$$

where, X_i is the input, X_{min} and X_{max} are the minimum and maximum values of the input respectively and X_n is the normalized input.

Fig. 2 shows the input output structure of the finalized ANN model after several trials with different inputs and different numbers of hidden neurons.

3.4 Spatial Analysis using Data Driven Modeling and Deterministic Modeling

After ANN model training, testing data was used to predict mean monthly precipitation in testing stations. A Kriging surface was generated using the training data and then the surface raster was used to predict mean monthly rainfall at the locations of testing stations. Both the predicted data sets from KM and ANN are compared with actual mean monthly data of the testing stations.

3.5 Model Performance

Performance of both the Kriging model and ANN model are evaluated using statistical error metrics. Five different error metrics are used to judge the models' performance considering all major error measures.

The root mean squared error is given by the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_{o,i} - P_{p,i})^2}{n}} \quad (6)$$

In Eq. 6, $P_{o,i}$ is the observed precipitation for observation *i*, $P_{p,i}$ is is the predicted precipitation for observation i and n is the number of observations.

RMSE is sensitive to large errors; hence the mean absolute relative error (MARE) is used to acknowledge the errors in lower magnitude events.

$$MARE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{P_{o,i} - P_{p,i}}{P_{o,i}}\right| \quad (7)$$

The drawback of this error is, it imposes heavier penalty in predicted values which are above the observed values than those are less than the observed values.

Very often, the coefficient of efficiency (Nash and Sutcliffe, 1970) is also used as an error measure.

$$E = 1.0 - \frac{\sum_{i=1}^{n}\left(P_{o,i} - P_{p,i}\right)^2}{\sum_{i=1}^{N}\left(P_{o,i} - \bar{P}_o\right)^2} \quad (8)$$

where $\bar{P}_o$ is the statistical mean of the observed precipitation.

The proportion of the total variance in the observed data is described by the coefficient of determination, R^2.

$$R^2 = \left[\frac{\sum_{i=1}^{n} (P_{o,i} - \bar{P}_o)(P_{p,i} - \bar{P}_p)}{\left[\sum_{i=1}^{n} (P_{o,i} - \bar{P}_o)^2\right]^{0.5} \left[\sum_{i=1}^{n} (P_{p,i} - \bar{P}_p)^2\right]^{0.5}} \right]^2 \quad (9)$$

But R^2 is insensitive to additive and proportional differences. Hence, the index of agreement (d) is used also as a goodness of fit.

$$d = 1.0 - \frac{\sum_{i=1}^{n} (P_{o,i} - P_{p,i})^2}{\sum_{i=1}^{n} (|P_{p,i} - \bar{P}_o| + |P_{o,i} - \bar{P}_o|)^2} \quad (10)$$

Finally, the mean error (ME) is also used to measure the 'bias' in the model.

$$ME = \frac{1}{n} \sum_{i=1}^{n} (P_{o,i} - P_{p,i}) \quad (11)$$

3.6 Data Preparation and Use of GIS

Two separate shape files of the precipitation stations were created using GIS- one for training stations, and another one was for testing stations. A Kriging surface was created using the training stations. Ordinary Kriging with spherical semivariogram was used for this purpose. 12 nearest data points were used for interpolation. Finally testing stations were used to extract data from the kriging surface.

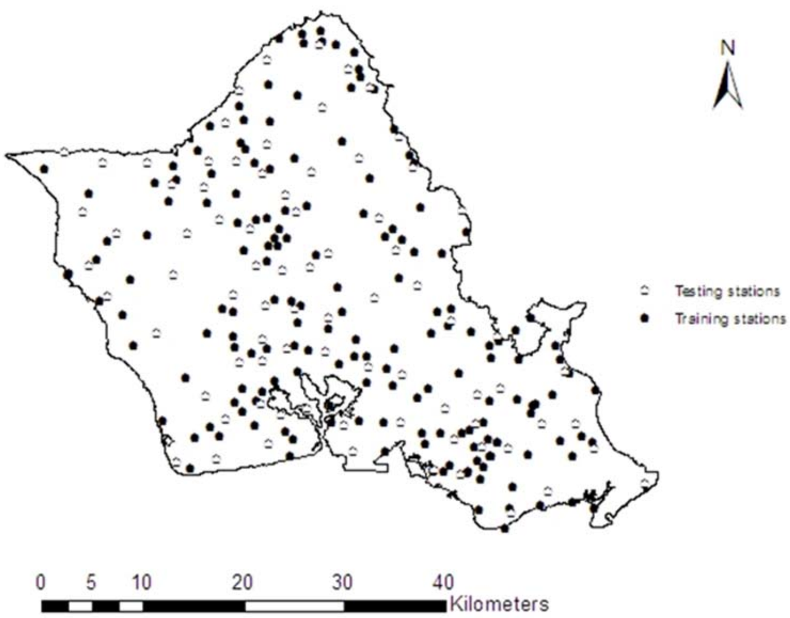

Figure 2: Training and testing stations' location.

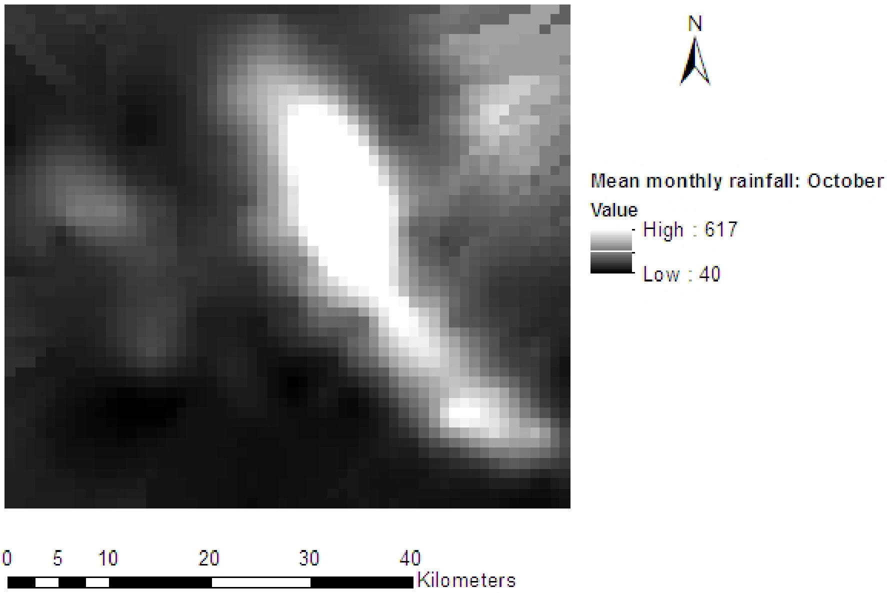

Figure 3: Generated Kriging surface.

4 Results and Discussions

4.1 Statistical summary of data

Preliminary statistical analysis of the proposed inputs did not show good correlation with output precipitation except the nearest station's precipitation and elevation of the precipitation station. However, some linear correlation is not the only parameters to decide about an input. Sometimes other types of correlations may exist between the input and output. In this case, It is assumed that the latitude and longitude alone may not have good correlations with precipitation; but together they plays an important role since they are the determining factors of spatial allocation of stations. Similarly, distance to nearby precipitation stations is important only when it is used with another input- precipitation at nearby station.

Parameters	***X***	***Y***	***E***	***S***	***L***	***Dw***	***Dp***	***P'***	***P***
Corr. vs. P	0.08	0.01	0.30	0.19	0.00	0.06	0.00	0.75	1.00
Skewness	-0.04	0.51	2.20	3.03	1.21	1.17	0.90	2.75	2.51
Kurtosis	-0.79	-0.68	7.33	16.78	0.59	1.00	1.07	8.28	7.59

Table 1. Correlations and distribution of data

Other two statistical measures indicated that the datasets were very close to normal distribution and most of the inputs have less peakedness except elevation and slope.

Parameters	Training	Testing
Min	40.03	43.58
Max	635.66	533.15
Mean	135.87	134.69
Stdev	97.86	100.12
Skewness	2.51	2.26
Kurtosis	7.59	5.64

Table 2. Statistical properties of training and testing data.

Total 250 precipitations stations were sorted out of 280; based on availability of mean monthly rainfall data for the month of October. The stations were divided into two sets: 170 stations for training and 80 stations for testing. The stations were divided into such a way so that the statistical parameters for training and testing were similar. Also the training and testing sets were spread over the whole study area.

4.2 Kriging Prediction

A Kriging surface was generated using 170 rainfall stations of training dataset. Using testing dataset shape file, corresponding station data were extracted from the Kriging surface. The observed and predicted data showed good correlation in scatter plot. Also the profile plot showed good fit of the prediction to the observed data.

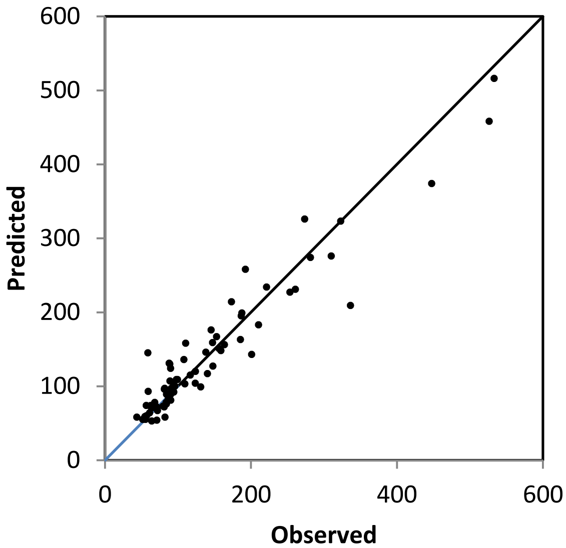

Figure 4; Scatter plot for Kriging model.

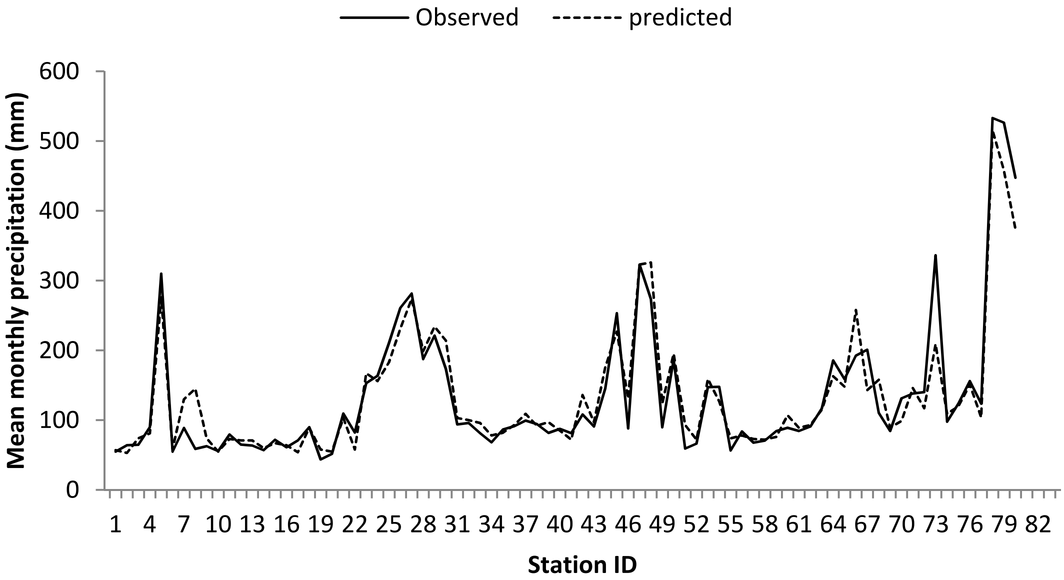

Figure 5: Profile plot for Kriging surface.

4.3 ANN Prediction

Using all of the 8 inputs, several ANN models were developed. The models with fives inputs- X, Y, E, D_P and P' gave the best result in terms of statistical metrics. Therefore, these inputs were finalized for the ANN model. As expected, training performance was better than testing performance.

Scatter plot showed good correlation of predicted data and observed data.

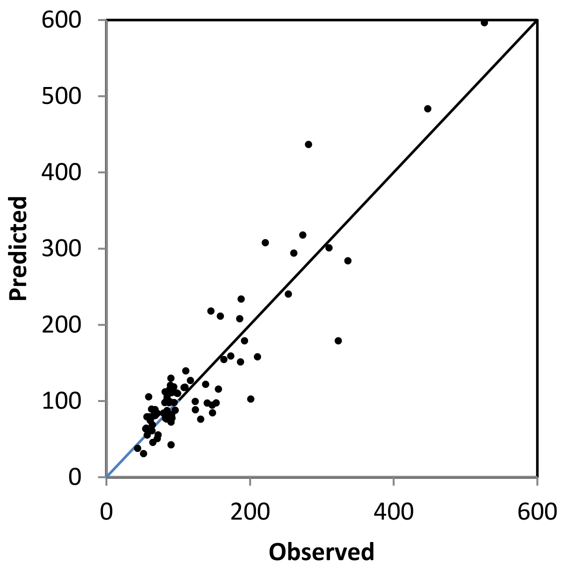

Figure 6: Scatter plot for ANN model.

Scatter plot indicated most of the important spatial inputs were integrated into the model. There was no sign of extrapolation in the plot. It also indicated that the sampling was good and inputs are derived correctly.

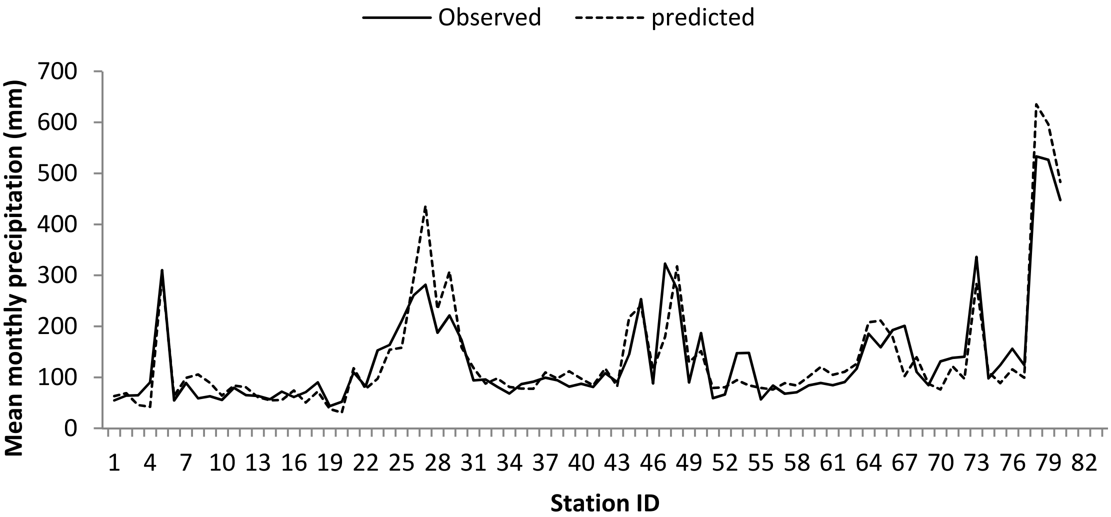

Figure 7: Profile plot for ANN model.

The profile plot also shows good fit with the observed data. The predicted data can follow the trend of the observed data with good accuracy.

4.4 Kriging and ANN Comparison

Statistical metrics for Kriging and ANN showed good performance in terms of fitting the observed data. However, Kriging showed slightly better performance than ANN.

But both Kriging and ANN model need optimum amount of information for good performance. For Kriging, more information is better for model. While considering the spatial domain, either too much or too little spatial information as inputs would result decreased performance of an ANN model (Luk et al., 2000). Therefore another 2 sets of Kriging models and ANN models were built with 50% and 25% of the total data used first to test the change in performance for both the ANN and Kriging model with change in sample size.

Error Metrics	Kriging	ANN
RMSE	28.75	40.99
MARE	0.15	0.22
E	0.92	0.83
R2	0.92	0.87
d	0.98	0.96
ME	-0.51	-3.21

Table 3. Model performace for Kriging and ANN

As indicated in the Fig. 9, statistical metrics' performance was decreased for both ANN model and Kriging model with decreasing of sample size. However, still Kriging showed better performance than ANN, though no significant win over ANN. But performance of the ANN model can be improved by generating a better model if more spatial inputs with good correlations with precipitation can be derived. Also if noise in the precipitation data (if any) can be reduced by taking better rainfall measurements from the stations; would eventually improve the ANN model.

5 Conclusions

In this study, a comparative study of Kriging and ANN was done in terms of rainfall pattern recognition in the O'ahu Island of Hawaii. Models were developed with data available online with the help of GIS. The followings are the outcome of this study:

- According to the developed ANN model, the major spatial factors affecting October precipitation in O'ahu are latitude, longitude and elevation.
- Distance to the nearby rainfall station and precipitation at that station if provided; increase the accuracy of prediction of ANN model.
- ANN model can predict rainfall with almost the similar accuracy of Kriging while the necessary spatial informations are provided.
- For spatially distributed data with good sampling (no visible cluster for any particular location), decrease of data points decreases the performance of both ANN and Kriging. Though both the models have similar performance for each sampling size.
- Kriging showed better performance than ANN; but there are scopes to increase ANN performance by incorporating more rainfall contributing factors into ANN model.
- ANN model can be a good alternative of Kriging for rainfall interpolation.

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An Effective Tool for Urban Land Acquisition: GIS

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KEY WORDS: GIS, Raster & Vector data, Spatial Queries, Good Governance and Sustainable Development.

ABSTRACT:

Land is an undoubtedly scarce and vital resource in urban areas. The World Urbanization Prospect concludes that a 67 percent of the world population will be living in urban areas in 2050. This tremendous pressure of population growth needs huge amount of land mass for new development or redevelopment. The scarcity and growing prices of land puts an extra momentum on this issue. The aforesaid issues make the land acquisition process extremely crucial with a view to attain the good governance in city areas. The geo-spatial technology can handle this burning agenda with great efficiency and care. This study has tried to ensure the land acquisition process impartial, transparent and quick through the deployment of GIS technology. The study area is in one of the most populous capital city in the world, Dhaka, Bangladesh. This would be mega city of 22.9 million in 2025. The city development authority intends to extend a road connection in the study area. The initiative involves huge amount of land acquisition in the urban fringe areas. They would like to know the parcels which will be affected by this new development. The exact amount of the land parcels needed to be acquired is also to be found. This information would then be coupled with the corresponding owner for their respective compensation. The total process is associated with lot of disputes and complexities. Here the necessity of utilizing GIS technology comes forward.

Through a series of spatial queries relevant information regarding the affected parcels and corresponding owners are processed with the help of powerful field calculator. The derived information is stored in geo-database for further use. The spatial information stored in geo-database is utilized for detailed compensation calculation and legal noticing to the respective owners. The different arbitrary rates are used for various landuse categories like Residential, Commercial or Agricultural types. There are also a sets of maps produced in this connection like map showing building heights; map showing type of the building materials and so on. The result of this study will greatly assist associated professionals along with other relevant ones to achieve the sustainable development through the enhancement process of good governance. They can have the access to all data related to land acquisition and compensation in a single source with the help of Geographic Information System. This is in fact a very good mechanism for achieving impartial and people oriented decision in the shortest possible time.

1 Introduction

Dhaka is one of the fastest growing megacities in the world. It requires updating of her services and facilities continuously in order to meet the ever increasing demand with a view to keeping it functioning. The case study involves an extension of the part of a major road network where land acquisition is the most critical part. This land acquisition task is even very difficult and challenging in the way that the land parcel information is stored in paper maps and it is hand written in Benglai fonts. Any approach other than GIS can do a little to solve this problem rather it creates a lots disputes involving public interests. An effective utilization of GIS technology can solve the critical problem even up to the stakeholders' compensations in very impartial way.

2 Methodology

The study was started with the collection of parcel maps (Mouza Maps) and then they were scanned in full scale. These data sets were used in GIS system as raster data source. The raster data sets are converted in vector ones with the help of ArcScan tool available in the ArcGIS system. Having completed the parcel information all other related data about the parcel owners are incorporated in GIS. Once the data sets are ready in GIS system a series of attribute and spatial queries are materialized in order to get the actual amount land to be acquired along with the respective compensation in local currencies.

3 Data and Software

This initiative contains the utilization of both raster and vector types of data in GIS. The original parcel information about the plot boundary and numbers were in the raster format which was converted into vector format later. The information about the owners was provided from the city development authority. There were some other information which was collected from the direct survey such as information about the landuse in each affected parcels. There was also an updated satellite image which was used for data validation purpose.

4 Implementation

This section includes Data Preparation, Analysis and Reporting.

4.1 Data Preparation

The scanned raster data which contains the parcel boundary and plot number are first geo-referenced before digitization. The raster date sets are then converted into vector data format using ArcScan tool available in the ArcGIS system. This process is completed with semi-automatic techniques due to the variations in the raster image quality where a lot of importance was given to the quality vector data.

The survey data along with other relevant data sets were put together in GIS database for further use in the analysis. The information about the parcel owner is attached to the prepared data sets with a view to deriving the actual amount land to be acquired from each plot as well as the corresponding compensation in monetary term. A number of maps were also prepared for providing better impression about the project area such as landuse map, map with building stories and map with type of the construction materials.

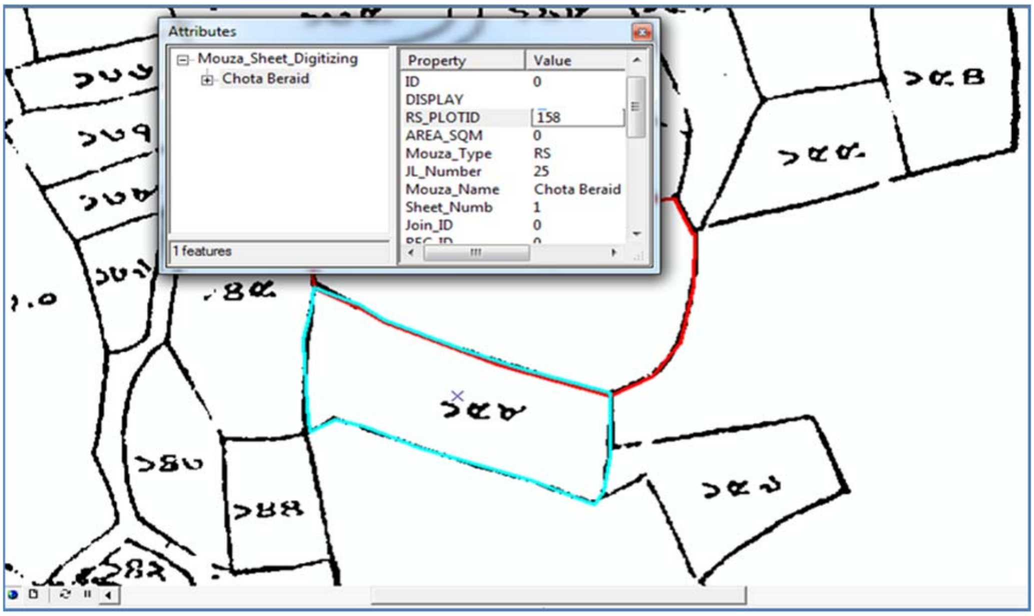

Figure 1: Data preparation.

4.2 Analysis

A line shape file of the Road link was provided in order to start with case study. Since the road link is intended to widen in 300 meters a buffer with the same was created along the road alignment. The buffered road poly was used to make a spatial query which returned the number of parcels to be affected by the extension project. The result of the spatial query was extorted as a new shape file for using in the subsequent sections. The exported shape was then clipped with the road buffer polygon in order to get the exact amount land to be acquired from each parcel.

As there was information available about the affected parcel owners the exact amount of land to be acquired against each of the owner was made ready for the compensation calculation. The according the given criteria the amount of compensation was different for each of the land use category such as compensation value for a single unit is higher than that of the agricultural landuse.

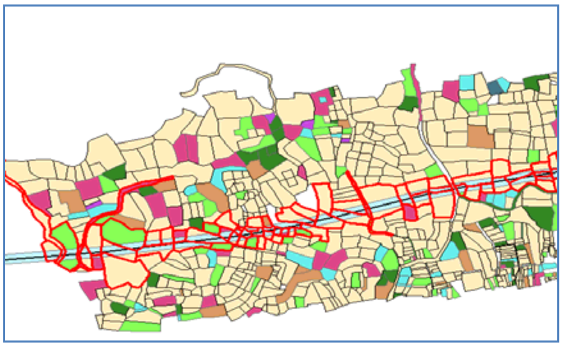

Figure 4.2.1: Parcels to be affected

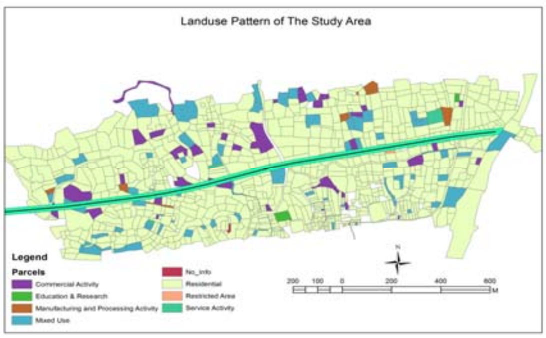

Figure 4.2.2: Landuse Map of Study Area

5 Reporting

The processed data sets were stored in GIS database along with other relevant tabular data which can make the land acquisition at one stop service. We can augment the functionality of this process using the "Mail Merge" option of the MS Word that can facilitate the automated land acquisition notice for the each of the affected land owners indicating the amount of land, rate of the land value as well as total compensation.

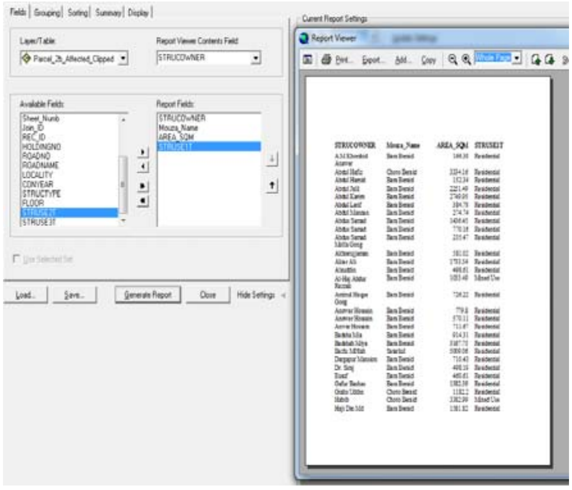

Figure 4.3.1: Building Query in GIS

SL	Owner Name	RS_Plot ID	Parcel_Area m2	Area_2b_Acquired m2	Landuse	Comp/m2(tk)
1	Bazlu M0llah	128	5009.06	290.18	Residential	3000.00
2	Hazi Arshad Khan	140	6136.98	1061.06	Residential	3000.00
3	Monumita	141	3860.42	248.16	Residential	3000.00
4	Md. Abdul Motin	143	1597.39	739.58	Commercial	6000.00
5	Giahs Uddin	144	1182.2	154.92	Residential	3000.00
6	Abdul Hafiz	145	3334.16	713.82	Residential	3000.00
7	Kalam	157	7254.83	967.64	Commercial	6000.00
8	Habib	158	3382.99	1985.95	Mixed Use	2000.00
9	Mofiz	160	9050	192.37	Residential	3000.00
10	Md Chand Miya	973	8070.09	2572.01	Residential	3000.00
11	Md, Isahaque	976	1498.92	21.59	Residential	3000.00
12	Kazi Golam Rahman	978	1732.26	1062.74	Residential	3000.00
13	Md, Najrul Islam	979	2173.55	350.96	Residential	3000.00
14	Mofijul Islam	980	1862.6	873.84	Residential	3000.00
15	Md, Azom Khan	985	1635.62	177.36	Residential	3000.00
16	Ujjal Mia	986	763.16	753.23	Residential	3000.00
17	Md, Saheb Ali Gazi	987	4444.3	913.7	Mixed Use	2000.00
18	Haji Din Md	1002	1581.82	541.69	Residential	3000.00
19	Haji Nur Md Mollah	1003	781.37	633	Residential	3000.00
20	Badshah Miya	1004	3167.75	1314.39	Residential	3000.00
21	Mst Rawshan Ara	1005	940.26	449.17	Residential	3000.00
22	Mir Motahar Hossain	1006	1844.37	1060.75	Residential	3000.00

Figure 4.3.2: Generated Output Table a

5.1 Output

The generated database is capable of storing of spatial data and non-spatial data like image, spread sheet, text, audio and video. The outputs of the database can be made in the form of maps, report, chart, processed information, specialized data support etc. This can perform as one of the great decision support tool in connection with land acquisition especially in urban areas.

Landuse	Number
Commercial	7
Mixed Use	9
Residential	99
Restricted Area	1
(blank)	
Grand Total	116

Figure 5.1: Parcels in Landuse Category

Row Labels	Count of Stories
1 Storied Building	81
2 Storied Building	13
3 Storied Building	2
4 Storied Building	7
5 Storied Building	11
6 Storied Building	2
(blank)	
Grand Total	116

Figure 5.2: Affected Buildings in Storeis a

6 Conclusions

The outcome of this study will greatly assist associated professionals in urban design and development along with other relevant ones who can play an active role in achieving the sustainable development through the enhancement process of good governance. This can also help in setting up transparency and equity in urban governace. They can have the access to all data related to land acquisition and compensation in a single source with the help of Geographic Information System. This is expected to be a very good mechanism for achieving impartial and people oriented decision in the shortest possible time.

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Web-oriented database & geoprocessing services for the documentation of Synthetic Aperture Radar scenes

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KEY WORDS: Synthetic Aperture Radar (SAR) Radar Remote Sensing, Relational Database Management System (RDBMS), Microsoft SQL Server, Web GIS, Geoprocessing services, ArcGIS, data documentation, automation, Python

ABSTRACT:

The growing concern for the negative impacts derived from mining activities implies the need of a strategy for the detection and monitoring of mining impacts. For this purpose, techniques based on Radar Remote Sensing and Geographical Information Systems can be successfully implemented. However, the vast amounts of data generated by this kind of projects lead to the need of data documentation, so that their comprehension can be guaranteed over time. This article describes a system conceived to secure maintenance, long-term understanding, fast-user-friendly data access and reuse of data.

Firstly, the characteristics of the data and their behavior were implemented on a Relational Database Management System to guarantee a centralized and secure data storage. Besides, a user-friendly desktop application was programmed to facilitate the creation of a standard documentation common to all projects. Finally, a Web GIS architecture was implemented to automatically populate the database and enable the user-friendly creation and manipulation of data via Intranet.

1 Introduction

Mining is one of the oldest human activities and has become an important sector in the world economy (Bell & Donnelly, 2006). Environmental impacts related to the mining industry, such as ground deformation or landslides, have raised concerns about health hazards and potential socio-economic damages derived from its activities. This fact can be seen reflected on the incorporation of prevention and mitigation measures in international and national laws, such as the German legislation.

Germany is marked by a long mining tradition and was one of the most relevant mining countries in Europe (Bartels & Slotta, 2012). German mining legislation already contemplates the need to design and implement a strategy for the detection, monitoring and management of negative impacts derived from mining activities. Some regulations can be found for example under the Federal Mining Act of 1980 (Bundesberggesetz) or the law of Environmental Impact Assessment of 1990 (Gesetz über die Umweltverträglichkeitsprüfung). This strategy should include not only the initiation, exploitation and closing phases, but also the detection and post-monitoring of potentially affected areas. To this purpose, the Institute of Geotechnical Engineering and Mine Surveying (IGMC) at Clausthal University of Technology (Germany) is involved in the detection, modeling and monitoring of environmental impacts derived from active and abandoned mining based on Surveying, Remote Sensing techniques and Geographical Information Systems (TU Clausthal, 2014).

On the one hand, the analysis of high resolution remote sensing data provides a cost-effective methodology to detect and analyze hazards related to mining activities (Mertikas et al., 2003), for instance, providing information about surface deformation (Charou et.al, 2010). Maini & Agrawal (2011) recalled that "Satellites are the main remote sensing platform used today" and describe some of the advantages that Satellites have over other platforms, such as continuous collection of data, broad coverage or accurate data mapping. Indeed, satellite remote sensing allowed mapping areas in where traditional techniques encounter limited access and higher cost of implementation (Savitsky & Lacher, 1998). Furthermore, the analysis of historical satellite data has the potential to describe pre-mining stages (Düzgün, & Demirel, 2011), being essential to distinguish between the environmental impacts related to mining, the ones generated by other activities and the expected natural development of the area of study.

On the other hand, Geographical Information Systems (GIS) provides a powerful tool to geoprocess the large amount of data characteristic of this kind of projects. Thus, the extraction, combination and analysis of remote sensing and other related geographical data has the potential to detect and monitor mining environmental impacts.

This project focused on Synthetic Aperture Radar (SAR) Remote Sensing, a type of imaging radar system where a small radar antenna is moved along the platform flight path to simulate a longer antenna, and consequently to increase the resolution of the image (Franceschetti & Lanari, 1999). SAR radar raw data can be processed in terms of range and azimuth producing Single Look Complex (SLC) products, which contains measures of amplitude and phase (Maitre, 2013) that can provide valuable information about mining environmental impacts.

The vast amounts of geographical data acquired for SAR Remote Sensing projects at the IGMC led to the need of data documentation, so that their comprehension can be guaranteed over time. Hence, the purpose of this project was the development of a database for the centralized storage and documentation of SAR scenes to secure maintenance, long-term understanding, fast retrieval, and therefore reuse of data. Besides, a user-friendly desktop application was programmed to facilitate the creation of a standard documentation common to all projects. Furthermore, a Web-based GIS architecture was designed to populate the database and allow the creation and modification of data via Intranet.

2 Methodology

2.1 System architecture planning

The architecture of the system was planned to achieve the required functionality. First, a relational database management system (Microsoft SQL Server 2012) was used to guarantee a centralized and secure data storage. Then, a Web GIS was implemented with ArcGIS 10.2.1 (server side) in order to allow users to easily populate and access the database through a Web browser (client side).

The system was deployed as a one-single machine on a virtualized environment in order to reduce provisioning time and costs related to new physical servers. Though virtualization might lead to a reduction in software performance, the light nature of data and the potential low number of requests to the server were expected not to affect the quality of the application.

Besides, Integrated Windows Authentication (IWA) was implemented to manage users and roles via Windows Active Directory and therefore to make use of the currently existing accounts on the local network. Thus, the system was configured to allow data access depending on Windows logins and to keep a track of users creating and editing features.

2.2 Database design & implementation

The first step was the identification of geographical and non-geographical data related to radar scenes which are relevant in the data documentation for the SAR projects at IGMC. Therefore, it was essential to contact the main users in order to identify which objects and attributes should be included. These entities, their relationships and properties where documented with an entity-relational (ER) model (see Figure 1) and implemented on an enterprise database (Microsoft SQL Server 2012). The database was configured to ensure user specific restrictions and enable the required geodatabase functionality provided by ArcGIS, such as attachments or editor tracking.

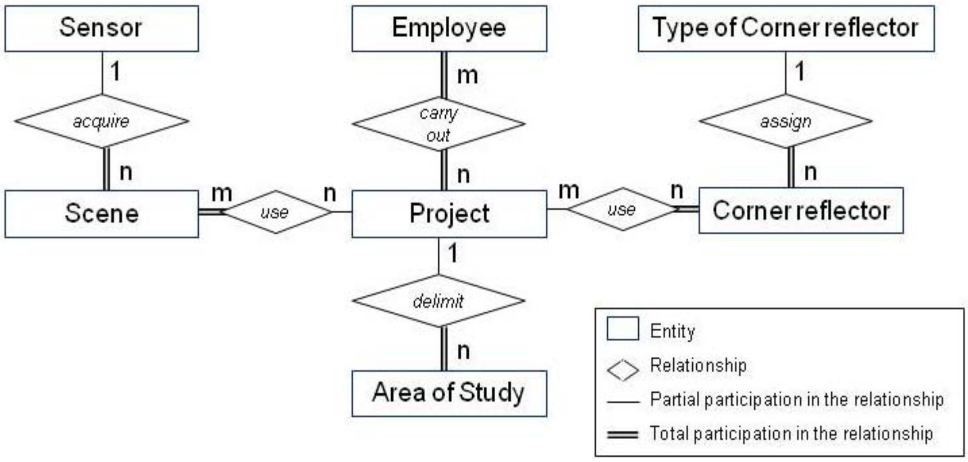

Figure 1: Entity-relational model of the developed database: Model based on the Entity-relational diagram proposed by Toube (2012). One sensor can acquire several scenes, but each scene is acquired only by one sensor. One scene can be used in different projects and one project usually makes use of more than one scene. One project is usually carried out by different employees, and one employee carries out normally several projects. One project might delimit different areas of study, but each selected area of study is delimited by one project. One project usually makes use of more than one corner reflector and one corner reflector can be used in different projects. One corner reflector can be assigned only one corner reflector type. But one corner reflector type can be assigned to many corner reflectors.

2.3 Development of the desktop application

For the purpose of ensuring a long-term understanding of the acquired radar data and facilitating their reuse in future projects, a desktop application was developed so that users could easily create a standard documentation based on the ER model.

On the one hand, a Graphical User Interface (GUI) was built with the toolkit for Python "Tkinter" providing a user-friendly interface to fill out the attributes of the ER model, such as relevant technical characteristics of satellites. On the other hand, Python 2.7.5 was used to automatically process the given information and generate a digital documentation with a structure common to all projects.

Furthermore, the application was also designed to automatically supervise the correct input of mandatory attributes and values involved in relationships, as well as to ensure data integrity.

2.4 Automatic population of the database and development of the Web Application

Firstly, Python was used to develop the geoprocessing tools to automatically populate the database out of the SLC parameter files and the documentation generated by the desktop application. Besides, a geoprocessing task was also programmed to calculate the Bounding Boxes of the SAR scenes and the area of study, writing the corresponding geometry to existing feature classes.

The next stage was the development of a Web-based GIS architecture with ArcGIS 10.2.1 for Server to provide users with fast data access and to facilitate the edition of attributes over the Intranet. First of all, the geoprocessing tools where published as a service using Model Builder and ArcGIS 10.2.1 for Desktop. After that, the Integrated Windows Authentication was achieved through the configuration of Internet Information Services 7 (IIS) and ArcGIS 10.2.1 Web Adaptor for IIS, using a self-signed certificate. Finally, the Web application was implemented with ArcGIS Viewer 3.2 for Silverlight.

3 Outcomes

3.1 Desktop application

The interface of desktop application (see Figure 2) was organized in different tabs, dividing the ER model in three areas (projects, sensors and corner reflectors) in order to facilitate an intuitive navigation. The first tab 'Project' was designed so that users provide information related to employees, area of study and other relevant details. Here, users can automatically calculate the Bounding Box and other attributes of the area of study by uploading Resampled Single Look Complex (RSLC) files, produced by resampling SLC images to a common master scene. Although a description of the satellites and sensors used at IGMC were already stored in the database, a second tab 'Sensors' was also included for future new satellites. Finally, the tab 'Corner reflectors' was planned to document which corner reflectors were used in each project. An extra tab was included to allow users to easily update the values stored inside the list boxes, if required.

Additionally, the application was programmed to assist users to semi-automatically fill out the data entries, ensure data integrity and guarantee the correct operation of the relationships. For instance, if a project name is not always provided exactly with the same value, its participation in a relationship will not be recognized. Furthermore, the total records of projects and employees increase over the years, as personnel change and new projects are acquired. Having considered this, other python scripts were created to automatically read and update these values via Intranet and make them accessible by the desktop application every time that the software was executed.

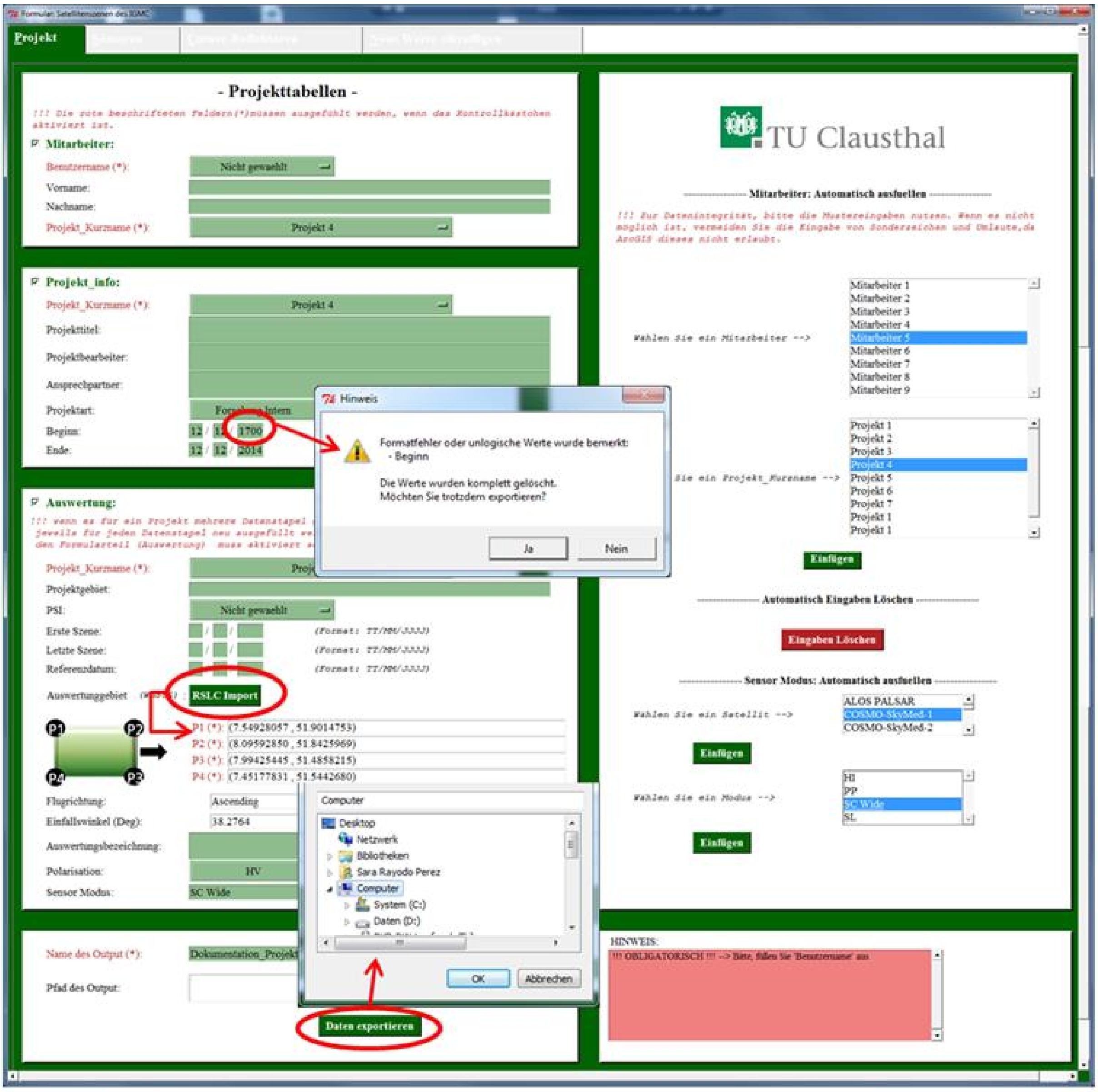

Figure 2. Desktop application for the documentation of radar scenes:

View of the first tab of the desktop application to fill out information related to projects, sensors and corner reflectors. The right column assists users to semi-automatically fill out the da entries. The 'Tip' box (Hinweis) provides information about compulsory entries if they are not provided, eg. user name (Benutzername) of employees. A window pops up, if errors or illogical values were found in some entries, eg. a year was given when satellites did not exit. Once the information has been given in the right format and all the mandatory entries have been provided, the button 'Data export' (Daten exportieren) allows users to export the information to a txt file, creating a standard documentation for the projects.

3.2 Web Application

The Web application was designed to easily create and modify data in the database using a Web browser supporting Microsoft Silverlight 5 (such as Mozilla Firefox or Google Chrome) and an authorized Windows login (see Figure 3).

Four geoprocessing services allowed users to generate new data by processing the SLC parameter and documentation files regarding projects, sensors and corner reflectors. Besides, existing attributes could also be edited using the table of attributes. In both cases, creation and modification were registered in the database, keeping track of the date and user id that created or edited each feature.

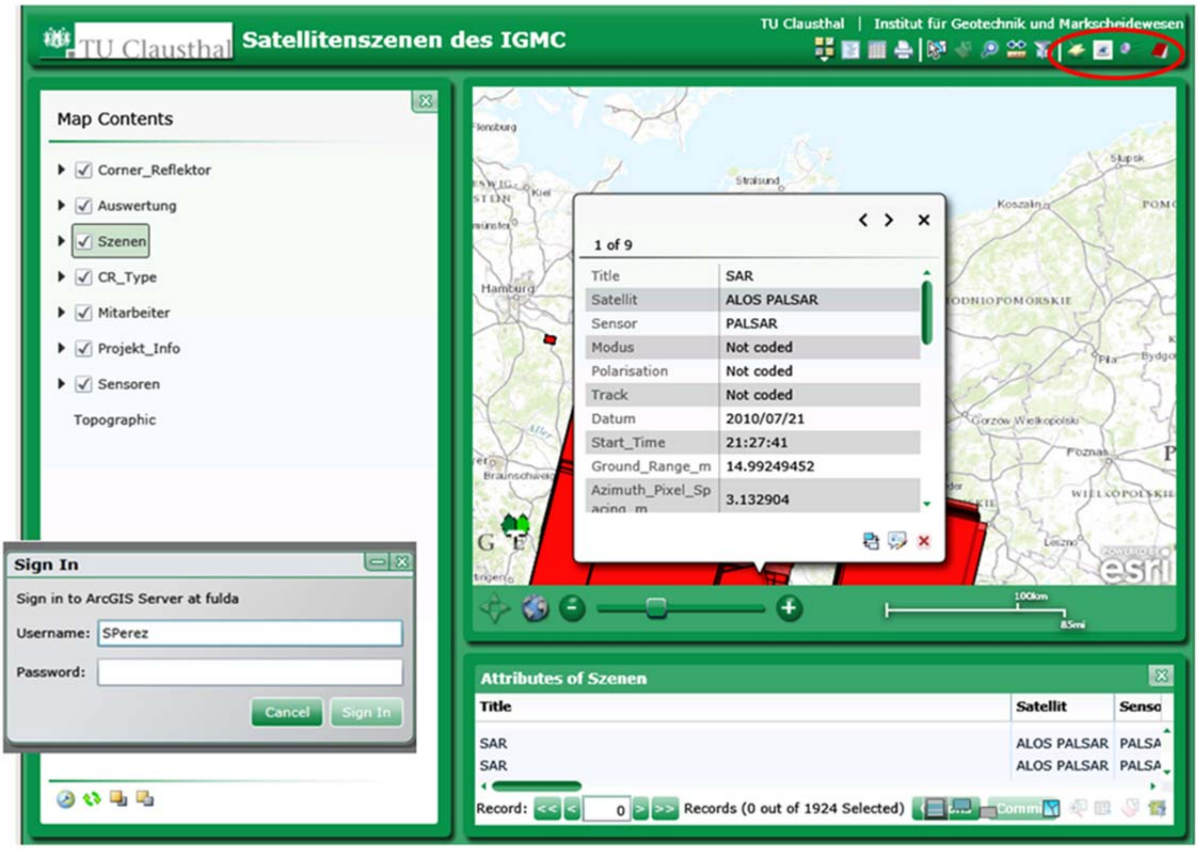

Figure 3. Web application for the documentation of SAR scenes at IGMC:

Users access the Web application with a Web browser supporting Microsoft Silverlight 5, an authorized Windows login and password. On the top of the application, the links to the TU Clausthal Clausthal and IGMC Websites, basic functionality (such as open table of attributes or the printing tool) and the tools for the geoprocessing of Single Look Complex parameter files and the documentation generated by the desktop application can be found. Data can be accessed and edited in different ways; using the Map Contents, opening the table of attributes and selecting the feature on the map.

Apart from the normal navigation functionality, users were also able to visualize and edit the related records regarding the relationships of the ER model and attach photos or documents (see Figure 4), for example to visualized a corner reflector.

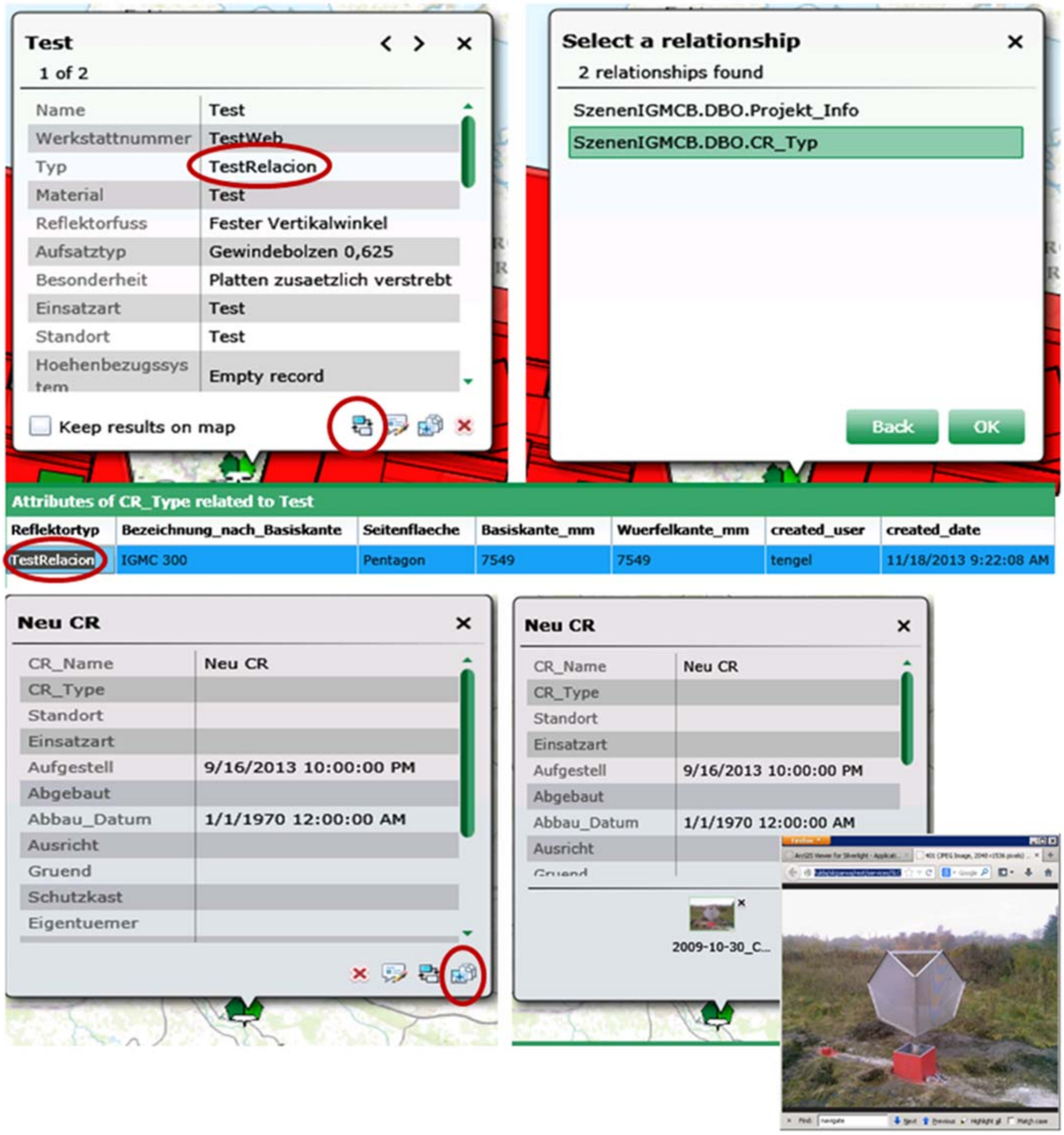

Figure 4: Visualization of related records and attachments: The Web application allows users to find all the related records for a determinate feature, based on a common value (top). Users are also allowed to upload and visualize photos or documents related to a

4 Conclusions & Discussion

4.1 A good strategy for data documentation and maintenance save time and economical resources

Satellite remote sensing and Geographical Information Systems provide a suitable technology for the detection, analysis and monitoring of environmental impacts derived from mining activities. Because this kind of projects usually entails a large volume of data, a good planning for data documentation and maintenance are required to secure a long-term understanding, fast retrieval and reuse of data. Consequently, including digital data documentation in the strategy of a company is likely to save time and economical resources.

Furthermore, automation of geoprocessing tasks together with the design of user-friendly interfaces allows users with less technical skills to document data; hence this strategy is also likely to reduce employee costs.

4.1.1 Suitability of the proposed system for data documentation

The proposed system provided a suitable Web-based GIS to populate the database and allow the creation and modification of data via Intranet. Furthermore, the implementation of the Integrate Windows Authentication allowed the control of users (windows logins) creating and editing features in the database.

For the concrete situation at the IGMC no database versioning was required, since only one employee per project was in charge of the documentation and data were rarely modified. However, it should be included as part of the data maintenance strategy, if versioning is implemented.

4.1.2 Advantages and disadvantages of Virtualization

Virtualization avoided the provisioning time and costs related to the acquisition of new physical servers. Nevertheless and although the implemented Software was supported on the virtual machine, a considerable reduction in the time of response was observed, compromising the administrator and user experience. As remarked by ESRI white paper (2010), running ArcGIS Server or any other application on virtual machines affects negatively their performance.

Taking into account the light nature of data and low number of requests, an increment of the resources assigned to the virtual machine could have solved the problem. Unfortunately, the high demand of resources (processing power, memory, etc) within the data center providing the virtualized environments led to restrictions and prevented this solution.

Potential alternatives to increase performance could be the acquisition of a new physical server or the use of a virtualized environment on one of the physical servers at IGMC. With the later scenario, the system could get advantages of the existing resources while keeping itself isolated. Consequently, impacts on running applications could be avoided in case of modifications in the system.

4.1.3 Limitations of the system for non-spatial tables

The ER model was planned to be implemented as a map service containing three feature classes ('Scene', 'Area of study' and 'Corner reflector') and four non-spatial tables ('Sensor', 'Employee', 'Project' and 'Type of corner reflector'), in order to expose only the desired data. However, the publication of the map service discovered that the non-spatial tables, unlike the layers, were not available in the table of contents. Indeed, only the records participating in relationships were able to be accessed.

This limitation entailed the unsuitableness of the system, since users were likely to require the attributes of the non-spatial tables in order to find their related records. For example, users were likely to search for a project name and find all the radar scenes that were used to monitor a certain area or which employees were involved in a project.

The first approach was the storage of the non-spatial tables as feature classes to make them available in the table of contents. However, a more suitable potential solution could be the use of query layers to dynamically retrieve data from non-spatial tables, since they are editable within map services with feature access enable from the version 10.2 (ESRI, 2014). This solution would be tested in future updates of the proposed system.

4.1.4 Implications for developing countries

The system could also be implemented with open source software, avoiding the high license fees related to the mentioned software. In that case, the capabilities, advantages and disadvantages of the planned software should be carefully analyzed during the first stages of the project. This, together with the potential availability of free and open environmental data, could be a great alternative for monitoring environmental impacts by organizations with restricted budgets. However open data quality and availability are likely to entail limitations.

Moreover, Radar Remote Sensing provides a more time-cost efficient technology in comparison with traditional geodetic techniques. Therefore, the combination of a good strategy for data documentation and maintenance, the implementation of open source software, free data and Radar Remote Sensing techniques, provides a powerful alternative for developing countries for the detection and monitoring of environmental impacts derived from mining activities.

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Road Crack Detection in Images Recorded by a Mobile Mapping System

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KEY WORDS: Camera, Detection, GPS/INS, Mapping, Mobile, Recording, Road Condition

ABSTRACT:

In this paper we focus on crack detection in RGB images, which is considered as one contribution to the analysis of pavements conditions. Processes of crack detection in the images are discussed and illustrated with some experiments. For collecting geo-referenced images an RBG camera is synchronized with a navigation sensor. The presented work contributes to our overall concept for road condition mapping which relies on an analysis of data collected by a camera, a laser scanner and a spectrometer.

1 Introduction

Precise information about the pavement condition is a key issue for the overall management of transportation infrastructure (Herold et al., 2003). The public road networks are degrading in many places, as necessary investments are postponed or withdrawn. In order to deploy available means in a most serviceable way, the evaluation and geo-referenced mapping of the pavement quality is an indispensable prerequisite for maintenance management. Manifest asphalt failures like pot-holes, cracks etc. entail significant geometrical perturbations of the smooth road surface; therefore most of the recent research has focused only on geometrical irregularities of the uppermost road layer; aside from asphalt failures, surface roughness is a widely considered geometric condition parameter (FGSV, 2001). Several commercial surveying companies have focused on road surface data acquisition using vehicle-based mobile mapping systems. The major concern of these companies is to capture high resolution images and dense laser point clouds. TÜV Rheinland Schniering GmbH e.g. has employed laser profilers along and across the driving direction to measure the unevenness in both longitudinal and transverse directions. Some other parameters such as general unevenness, virtual water depth or International Roughness Index (IRI) are derived from those profile data. From mobile acquired images, which are taken at very small exposure times of ~1/50000 s in order to avoid motion blur, even tiny cracks can be detected (TÜV Rheinland, 2014). Several methods have been developed for automatic crack detection. (Mancini et al., 2013) detected cracks from mobile recorded images. They applied Gradient Vector Flow snake and fuzzy logic techniques. (Maas, 2012) presented the Fly-fisher algorithm for crack detection which is based on edge detection through gradient operators. (Wei et al., 2010) proposed a method based on the Beamlet transform in order to detect the pavement cracks from raster images. They reported about a method which is robust against noise. Other possible methods for crack detection comprise support vector machine (Marques, 2012), wavelet transform (Subirats et al., 2004) and local binary pattern (Hu et al., 2010). (Kertész et al., 2008) introduced a cost efficient road pavement mapping system for pothole and crack recognition. They equipped a van vehicle with a GPS/INS unit, an RGB camera and a laser projector (5 mW, 660 nm Lasiris laser diode). The projected laser line is detected in the image. By taking advantage of the known geometric relationships between laser line and camera the height profile in space can be reconstructed and height changes on the track can be analyzed.

2 Sensor specification and data acquisition

At the University of Applied Sciences in Stuttgart, we have equipped vehicles with sensors for mobile data collection. The overall goal of this development is to support research and teaching with a highly configurable system. One of these configurations is visualized in Figure . An RGB camera (Canon 5D Mark II), a laser scanner (FARO Focus3D X 330), a Polytec spectrometer (Polytec PPS 2221) and a GNSS-aided inertial navigation system (Applanix POS LV 420) are integrated on a platform which is mounted on the top of a van.

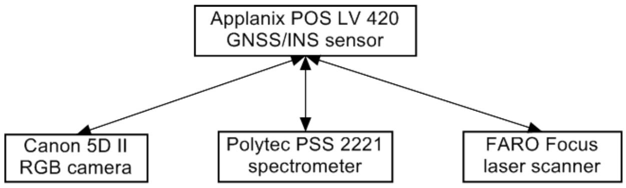

Figure 1. Sensor system used for road condition mapping

The camera used for this research is a digital single-lens reflex Canon 5D Mark II with 21 megapixels and a capability of 3.9 frames per second continuous shooting (Figure 2.). The relatively large sensor size of this camera (36 x 24 mm2) with the image size of 5616 x 3744 px gives the opportunity to take high resolution images. The lens of the camera has a focal length of 35 mm which causes a horizontal field of view of 54.43° and vertical field of view of 37.84°. There is an inclination angle of ca. 30° between the nadir line and the principal axis of the camera. The oblique view allows covering a bigger area and avoids recording parts of the vehicle. A camera output signal is generated by the hot-shoe for time synchronization purposes. The outgoing signal is amplified to fulfil the minimum voltage range needed for GNSS/INS synchronization. Temporal synchronization of the mapping sensors relies on the incoming pulses (TTL signal) recorded by POS LV 420 position and orientation system (Applanix, 2010). Figure 2 shows the RGB camera together with a laser scanner.

Figure 2. Canon camera, FARO laser scanner

As test area the neighborhood of the University of Applied Sciences in Stuttgart was selected, the path along which all datasets were recorded so far has a length of 850 m. By mounting the camera in nadir view at the back side of the vehicle, parts of the vehicle would be visible in the images. Therefore the images are recorded in an oblique view (Figure 2) and are rectified under the assumption of a planar road surface. Image capturing is performed either with a constant time increment, e.g. every second, or with a constant path increment, e.g. every 2 m. The images feature a high ground resolution of ca. 1 mm; they are used for automatic detection of asphalt failures, in particular for cracks.

3 Data processing and results

Major road failures are cracks, mends, potholes and ruts. The frequency of cracks is an important indicator of the road condition. According to (IFI, 2011), road conditions can be assessed as a weighted average of several contributions as unevenness, patches, depth of ruts, virtual water depth etc., where the highest weight is on the alligator cracks. This indicates the significance of cracks. Cracks and mends are detectable in RGB images of sufficient resolution as their reflectivity differs from the intact surface; our RGB images are well suited as their ground resolution amounts to ca. 1 mm. The figure shows the flowchart of crack detection using RGB images.

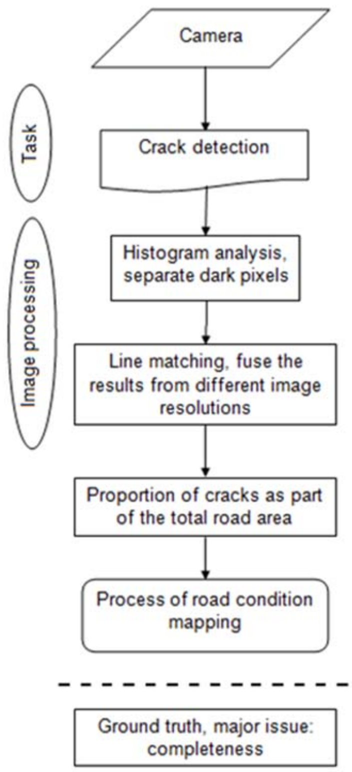

Figure 3: Flowchart of crack detection using RGB images

As a first step of our crack detection procedure, the grey-value histogram of an image is analyzed in order to separate the dark pixels from the background. For this purpose a thresholding is applied. Figure 4 shows the threshold represented as a red line. It is set halfway between the highest peak and the local maximum left of the highest peak. As all cracks lie on the left side of the highest peak, the thresholding yields a good preselection of possible crack pixels.

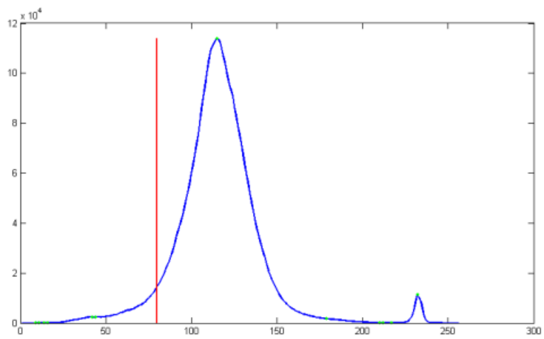

Figure 4. Histogram with threshold (red line).

The crack detection consists of a template matching; the matching is performed on several resolution levels in order to obtain cracks of various widths. We apply linear filters to the images by convolving the images with 18 quadratic masks, which are derived from a generating mask by successive rotations. The incremental rotation angle amounts to 10°. The width of the 2D filter masks is an odd number of pixels; a typical width is 51.

The generating mask m has the following structure:

$$m = \frac{1}{n(n-1)} \begin{bmatrix} 1 \ldots \ldots 1 & -(n-1) & 1 \ldots \ldots 1 \\ \ldots & -(n-1) & \ldots \\ \ldots & -(n-1) & \ldots \\ \ldots & \ldots & \ldots \\ \ldots & -(n-1) & \ldots \\ \ldots & -(n-1) & \ldots \\ 1 \ldots \ldots 1 & -(n-1) & 1 \ldots \ldots 1 \end{bmatrix}_{n \times n}$$

The derived masks are suited for the detection of line-like structures and therefore of cracks, which mostly appear as narrow, elongated areas in the images. While seams between different asphalt types could be extracted by edge detection methods, those methods are less suited for cracks: the latter do not represent discontinuities within the grey-value field, but rather dark segments within an otherwise quite homogeneous grey-value distribution. The given mask looks somewhat similar to the well-known operators for the approximation of second derivatives. Here it serves rather for the detection of elongated image parts with a sufficiently high grey-value difference compared to the neighbourhood, however. The images J_k of different resolutions are convoluted with all rotated masks $\mathrm{m_i}$ according to

$$M_{i,k} = J_k * m_i$$

The resulting images $M_{i,k}$ are thresholded and upsampled to the original resolution in order to obtain binary images $B_{i,k}$; as a threshold the empirical difference between the grey-value level of crack pixels and adjacent non-crack pixels is suitably selected. The images $B_{i,k}$ now contain elongated structures with a high negative grey-value difference compared to their neighbourhood. Let D denote the binary image where the sufficiently dark pixels are marked. The binary image of preliminary crack pixels is then computed according to

$$C = (\bigcup_{i,k} B_{i,k}) \cap D,$$

i.e. a pixel is considered as a crack pixel if it is marked in one of the binary images $B_{i,k}$ and if it is sufficiently dark.

Completeness of the crack detection is considered more important than correctness, as remaining false positive pixels are not of great impact for road condition mapping. However groups of detected crack pixels are eliminated if they represent a very small area or if the roundness of a region indicates an extensive area rather than a line-like structure. Weather conditions play a significant role in the crack detection. Sunny and rainy weather may both impair the crack detection using images, as shadows or wet ground both cause false detections. Figure 5 shows an example where a wet spot on the ground could be successfully filtered by the roundness criterion.

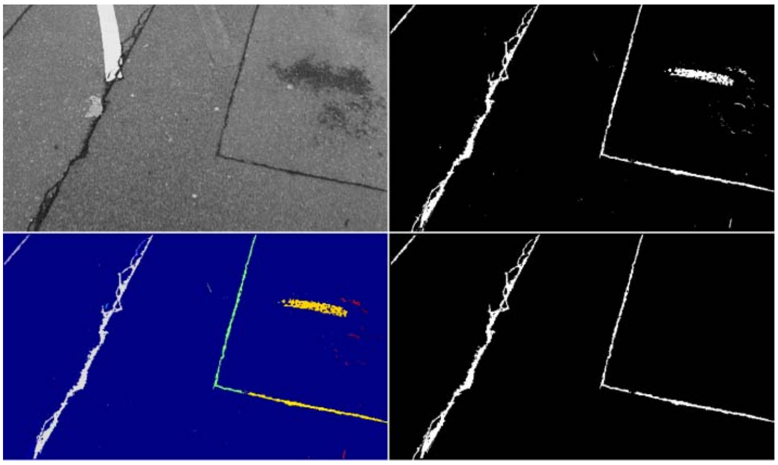

Figure 5. Greyscale image (upper left), binary result of crack detection (upper right), connected regions as symbolic image (lower left), binary image filtered by the roundness criterion (lower right).

Figure 6 shows a stream of images with their respective crack images. Obviously some small crack regions are still remaining even after filtering.

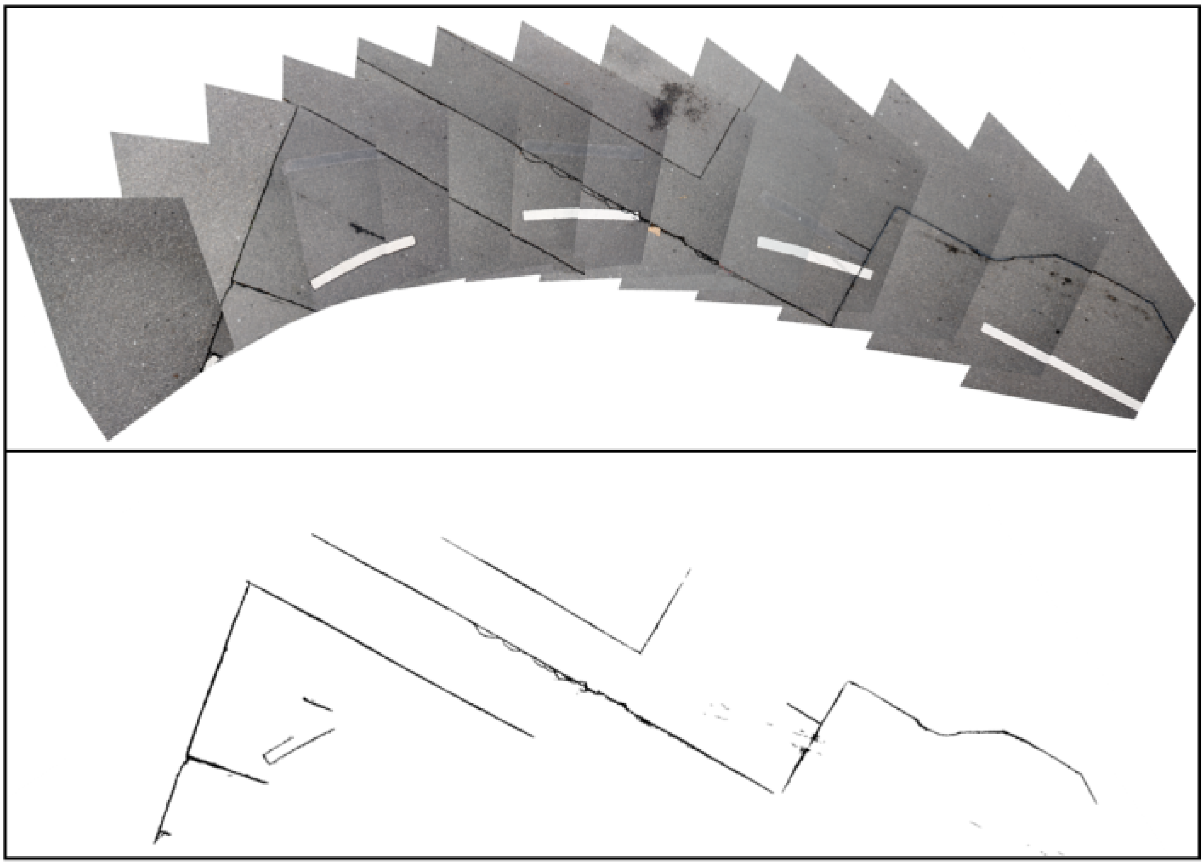

Figure 6. A stream of geocoded mobile images (top) with respective mosaicked crack images (bottom)

4 Conclusion

In this paper we presented a procedure for road crack detection using mobile recorded RGB images. With a histogram analysis and a multilevel line segment detection process cracks are localized in the geocoded images. The achievements so far are quite encouraging. The detected cracks will be used in future as one contribution to road surface monitoring.

Acknowledgement

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Big Data Analytics in Disaster Management

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KEYWORDS: Big data, Hadoop, MapReduce, Social media, Twitter feed, Facebook, Geoweb, Disaster

ABSTRACT

Digital data is overwhelming the computing power of the world. But this data also provides a plethora of opportunities too. This is especially true when it comes to the case of disaster management. In recent years there has been a spurt of interest and much research into the role of social media in disaster management. Rather than as a means of communicating hazard, risk and disaster perceptions and warnings, social media generated data like Facebook posts, Twitter feeds and the like are sought to be analyzed to arrive at a scale and spread analysis of disasters. This data is voluminous, different and when used in new ways to monitor and manage a disaster, qualifies the definition of big data and its four V's (volume, velocity, veracity and variety). The data shadows on the internet of Facebook likes, Flipkart orders, Google searches, Research Index citations, Tumblr pictures, You Tube videos – all add up to billions of bytes of information, most of which are geotagged, and which, if tweaked properly can bring up hidden, but critical geographical patterns of crowd responses. Big data snared in the geoweb can be of critical importance in big disaster events, if its analysis is mellowed by domain experts. Ushahidi, the Red Cross, the USGS all have had some success with social media analysis, for quite some time now. With mobile phone and 3G services permeating to the lowest ranks of society in the developing countries of the continents of Asia and Africa, which are the most prone to disasters, social media analytics with Big Data tools need urgent attention as a disaster response, management and mitigation tool. The information shared on disaster events in the social media, blog data on disasters, FB posts and Twitter feed analysis, and the geographical real time spread of social media messages as a monitor of disaster spread are techniques that could alter the way disaster information has so far been accessed and analyzed. This immense source of data, generated every microsecond, is the next great area of research and entrepreneurship, for the benefit of society through a process that is intimately interlinked with how the current population on earth communicates and thinks.

Integrated Approach on Identifying Groundwater Potential Zone in Kallar River Basin, Trivandrum, Kerala

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KEY WORDS: *Water Resource, Layer Integration, GIS, Remote Sensing, Groundwater Potential*

ABSTRACT

Water is a vital natural resource which is indispensable for the existence of all living matter, plant, animal and man (Ullah et al, 1972). Water resources are sources of water that are useful or potentially useful for agriculture, industry, house hold, recreational and environmental activities. The rainwater and water from melted ice that neither runs off along the surface nor evaporates but reaches under the surface of the land through pores and cracks, is called ground or underground water (Misra and Pandey 2009). The available surface and groundwater resources are inadequate to meet all the water requirements for all the purpose. Water demand already exceeded supply in many parts of the world and as world population continuous to rise at an unprecedented rate. Many more areas are expected to experience this imbalance in the near future. Due to urban population and industrial developments, vast number of wells using powerful pumps draw huge volumes of ground water to the surface, greatly altering nature's balance of ground water discharge and recharge (Alan et.al, 2009) Sufficiently thick weathered zone forms groundwater storage in bedrock areas but often may not provide regular supply of groundwater. The conventional approaches on groundwater investigation are ground based surveys and exploratory drilling which are time consuming and uneconomical. The traditional methods of searching sites for drilling of bore wells have not only had a poor success rate but even the places where such efforts have succeed, the bore wells are known to have dried up in a short period of time. Hence an integrated approach of remote sensing and GIS can help to demarcate groundwater potential zones in hard rock areas more easily and with accuracy (Neelima et. al, 2014). The present study has been conducted in Kallar River (41 Km length) basin in Nedumangad Taluk, Trivandrum District of Kerala. Kallu means 'stone' and aru means 'river' hence the name Kallar. It is a fifth order basin with an area of about 160 sq.km underlain by biotite gneiss, charnockite and khondalite. The basin has experienced a humid tropical climate. Survey of India Toposheet (1:25,000), Geological Survey of India maps, Google Terrain map, Google Satellite image downloaded from Google earth web application, Soil Map etc., have been adopted to generate various thematic layers. Weightage has been assigned for each thematic layer which are closely associate to explore the groundwater potential zone demarcation. Multi criteria analysis has been adopted for weighted layering in GIS Platform and the final result will evolve to depict the groundwater potential zone in Kallar River basin.

Prioritization of Watershed through Surface Runoff in Pambar River Basin Using SCS - CN Method in The Pambar River Basin, India

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KEYWORDS: *SCS – CN; Rainfall; Pambar; GIS; Remote Sensing*

ABSTRACT

A watershed is an area that drains water and other substances to a common outlet as concentrated drainage. Nowadays watershed management plays a vital role in water resources management. Watershed based on water resources management is necessary to plan and conserve the available resources. Remote Sensing (RS) and Geographic Information System (GIS) techniques can be effectively used to manage spatial and non-spatial database that represent the hydrologic characteristics of the watershed use as realistically as possible. The present study has been conducted on Pambar River is one of the major river drains the eastern slopes of Western Ghats covering Anamalai – Cardamom hill ranges. The Pambar watershed basin receives the average annual rainfall of 1109.9 mm mainly during June to September monsoon season (1961-2005). Sandy clay loam, Clay loam, silty clay loam, sandy clay, silty clay, or clay are the main soil group confined in this basin. Such a soil group obviously allows less water to infiltrate into it. The result runoff will be more. Due to high runoff potential and poor infiltration, drought like situation prevails in this area from December to June almost every year. So the conservation of watershed is very much essential to protect the environment. The watershed conservation priority number for the each watershed will be assigned according to the value generated from the runoff.

Evaluation and Prototyping of Spatial Data Infrastructure (SDI) Download Services

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KEY WORDS: *GIS, Web Feature Service, Spatial Data Infrastructure (SDI), Stored Query, INSPIRE.*

ABSTRACT

The Spatial Data Infrastructure (SDI) has been providing Geo-spatial data accessibility since nineties through interoperability to the Geo-spatial planning and research personals. The rapid improvement of Web GIS technology enhanced the working capability on Geo-spatial research through the sharing of Geo data along with advanced technical knowledge over the globe. The use of advanced open source software and server technology limits the dependency of proprietary software in this rapid growing industry of Geo Web technology. The main goal of this research was to develop a prototype SDI for academic purpose providing pre-defined Stored Query and direct access via Open Geospatial Consortium (OGC) specified Web Feature Service (WFS) version 2.0 based on the new approaches of spatial data download requested by INSPIRE (Infrastructure for Spatial Information in the European Community) in 2012. In this paper we describe the methods of developing SDI based on INSPIRE specification, 2012. The SDI was developed based on Open source software and server for example Geo-server and QGIS as client software to download and analyze the geo data. The official land parcels and building footprint data from a part of Stuttgart were used to test the stored queries along with direct download system via OGC specified WFS version 2.0 from the server. The results were evaluated based on the service quality, software availability, benefits as well as disadvantages.

1 Introduction

Spatial Data Infrastructure (SDI) is a framework for collection, process, development as well as sharing and editing of geospatial data along with the metadata, related technologies and policies among the people who are directly or indirectly involved in Geo-information can be academic, government or private organizations in regional, national or global level. It provides the possibilities to discover view or download spatial data through a catalogue service offered by the data provider within a community. According to SDI Cookbook, "The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academic and by citizens in general" (SDI Cookbook, 2008). Open Geo Spatial Consortium (OGC) has specified the standard for establishing web services for geo spatial data like Web Feature Service (WFS), Web Map Service (WMS) or Web Coverage Service (WCS) which allows users to share and edit geo spatial data across the web.

A successful establishment of SDI locally or nationally depends on the collaboration of different organizations in the point of view of policies, technologies or legal enforcement. Among some successful SDI initiatives all over the world Global Spatial Data Infrastructure (GSDI) is a voluntary organization that aims not only to cooperate or collaborate nationally or internationally for the development of SDI but also focuses on raising awareness issuing SDI for the social, economic and environmental development of a nation (GSDI, 2013). Another initiative in Europe is the Infrastructure for the Spatial Information in Europe (INSPIRE) has been taken by the 27 member states as a directive in May, 2007 till 2019 for establishing a SDI in Europe to support environmental policies and activities related to the environment (INSPIRE, 2013). In 2012, INSPIRE has published new rules and regulations to share and edit geo spatial data through Spatial Data Infrastructure. INSPIRE regulation allows the several possibilities to deliver spatial data to users:

- Predefined datasets delivered as Atom feed and described in an Open Search interface
- Predefined datasets delivered as stored queries based on WFS 2.0
- Direct access via WFS 2.0

This paper is based on an academic research to realize the data download possibilities according to INSPIRE stated rules and regulation stated in "Technical Guidance for the implementation of INSPIRE download services" published in June, 2012. For the limited research duration, the study have focused on last two possibilities of SDI data download service stated by INSPIRE. In this article we described the working process to develop a prototype SDI along with necessary outcomes as well as evaluates the possibilities of data download service according to INSPIRE directive.

Many researches on SDI and its development people have developed the accessibility, visibility and discovering functionality of spatial data. Google earth and maps, yahoo maps, Bing maps etc. are providing access to the spatial information to all over the world through Geo web technology. The Open Planning Project (TOPP) has started Geo Server in 2001 as a first step to increase accessibility to SDI frameworks. Then Open Geospatial Consortium (OGC) included the WFS standard, the protocol which makes available spatial data on the web has been included into GeoServer project. WMS and WCS were also created which are the service protocols to share or view maps in image format in raster or coverage format respectively (GeoServer, 2011). Another research finding by Justin Deoliveira in 2008 was the KML support for the Geo server which also helps the SDI technology connects with Google earth. Aneta J. Florczyk et al. (2012) has developed architecture to automatically generate metadata for the web resources. Jürgen Weichand (2012) has developed plugins named, "INSPIRE Atom Client Plugin for QGIS" and "WFS 2.0 Client for QGIS", which have been developed following the rules stated in "Technical Guidance for INSPIRE Download Services 3.0" from INSPIRE. WFS 2.0 Client for QGIS plugin has been used to test the achieved solution from the current research.

2 What is SDI?

SDI is common geo data storage within a community to share and edit geographic information all over the world based on World Wide Web. "The term Spatial Data Infrastructure was coined in 1993 by the U.S. National Research Council to denote a framework of technologies, policies, and institutional arrangements that together facilitate the creation, exchange, and use of geospatial data and related information resources across an information-sharing community" (ESRI, 2010). SDI uses a common policy and principle to collect, maintain and share the information among the users to protect also the data duplication, conflicts among usage of coordinate reference system and so on. Generally the geographic information in SDI are stored in a server in the form of geo-database, ESRI Shape file or other supported formats along with metadata and other related necessary technologies which are then visualized and downloaded through a web service. According to GSDI Cookbook, "An SDI must be more than a single data set or database; an SDI hosts geographic data and attributes, sufficient documentation (metadata), a means to discover, visualize, and evaluate the data (catalogues and Web mapping), and some method to provide access to the geographic data" (SDI Cookbook, 2008). The owner of the SDI is fully responsible for the collection, process, control and maintaining geospatial data based on some common set of rules, specifications, policy or standards.

Geospatial data visualization and download activities of an SDI are dependent on the Web Mapping technology which may be based on OGC standard of Web Map Service (WMS), Web Feature Service (WFS) or Web Coverage Service (WCS). Web Feature Service allows exchange of geo spatial feature across the web. It functions in a two way approach between client and server. In this process a client send a valid request to the service requesting an information which is stored in the server, then the service send the request to the server to match the informational request with the stored information in the server through HTTP protocol. After matching the requested information server send a response to the service which is then sent by the service to the client. The clients can be several web browsers like Safari, Google Chrome or Firefox and also can be Desktop software client capable of serving interoperability system.

The current version of OGC specified WFS standard is 2.0.0. In this version OGC has specified 12 operations with different capabilities which are GetCapabilities, DescribeFeatureType, GetFeature, LockFeature, Transaction, GetFeatureWithLock, GetGMLObject (older was GetPropertyValue), CreateStoredQuery, DropStoredQuery, ListStoredQueries and DescribeStoredQueries. OGC has started specifying the standard WFS with the WFS standard version 1.0 in 2002 which was then improved with two new operations named GetGMLObject and GetFeatureWithLock in 2005 with new version 1.1.0. In the latest version 2.0.0 OGC has changed a lot in the specification with new five operations including the operations to manage stored queries for querying the pre-defined dataset from the server. More details about the standard as well as implementation specification of WFS, operations available, request encoding are available in the OGC published documents that are OpenGIS Web Feature Service 2.0 Interface Standard (also ISO 19142) and OpenGIS Web Feature Service 2.0 Implementation Specification, available in the following links: http://www.opengeospatial.org/standards/wfs.

3 Methodology

3.1 Data preparation and preprocessing

The data used to implement the prototype SDI has been taken from PING (Plattform für Interoperable Nutzung von Geodaten) Project running in Hft-Stuttgart. The data were the Landuse and Cadastral information from Jagstfeld in Bad friedrichshall area (Figure 3.1) near Stuttgart in the form of ESRI shape file and Personal Geo-database.

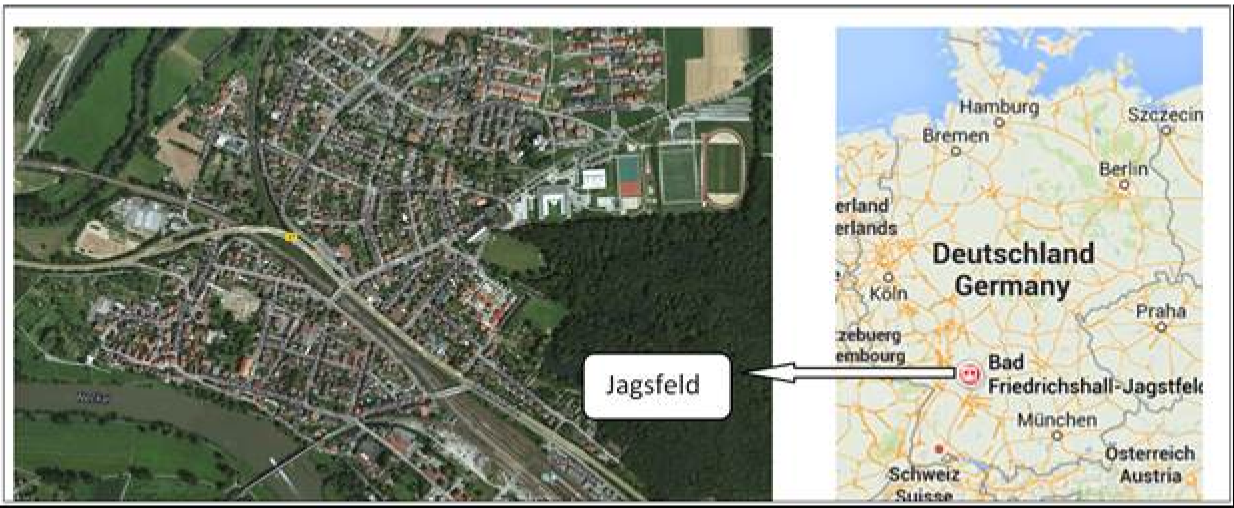

Figure 1: Study Area (Source: Google Map)

The main concept of the current study comes from the Technical Guidance for INSPIRE Download Services, published in June, 2012 by INSPIRE. SDI can be implemented based on different policies or advanced technologies depending on the organization who are implementing it. For the implementation of WFS 2.0 including Stored Query in the prototype SDI, the first task was to install necessary software and server. As server software Geoserver has been chosen as it is an open source software server which is written in Java that allows users to share and edit geospatial data by creating web services. The server which is used in this study implementation of SDI is the local machine as the study has implemented a prototype SDI under local host using port: 8080. Then Geo Server was installed fulfilling the requirements to avoid difficulties in running the server. Another important part is to look for the supported coordinate system. If found no matches with the predefined dataset coordinate system then it must be edited in the SRS list in WKT format (GeoServer, 2013). Geoserver supports both the PostGIS database and ESRI shape file to upload geo data. For PostGIS database then postgresql 9.3 has been installed with the extension PostGIS 2.0. The study has uploaded the geo data in both the two format in the geoserver. As a client to download and analyze geo data QGIS has been installed with the newly developed plugin named

"WFS 2.0 Client for QGIS". For writing and editing necessary XML files, Notepad++ has been used in this research.

3.2 Web Service Creation

The process and workflow followed in creation of web services are illustrated in figure 3.2. For the creation of web service like WFS 2.0 the first task was to create a workspace in geo server. A specific name is needed for the workspace as an Identification of the published datasets which will be used as the namespace for the dataset in the web service. Another requirement is a URL to specify the location path of the published dataset. Next step is to create a data store specifying the data location stored inside the server. Then it is important to configure necessary service metadata for WFS. Geo server provides some metadata by default which can be modified and configured with owner's information metadata. After configuring the service metadata the features are published in Geo server by configuring necessary dataset metadata. By publishing the dataset in Geo server, the dataset were uploaded in the Geo server. For WFS Geo server provides the version WFS 2.0 by default. So, it is possible to retrieve the feature information or service metadata configuration through the GET request URL to WFS 2.0. With a HTTP request[1] the Capabilities documents is retrieved to get the service metadata:

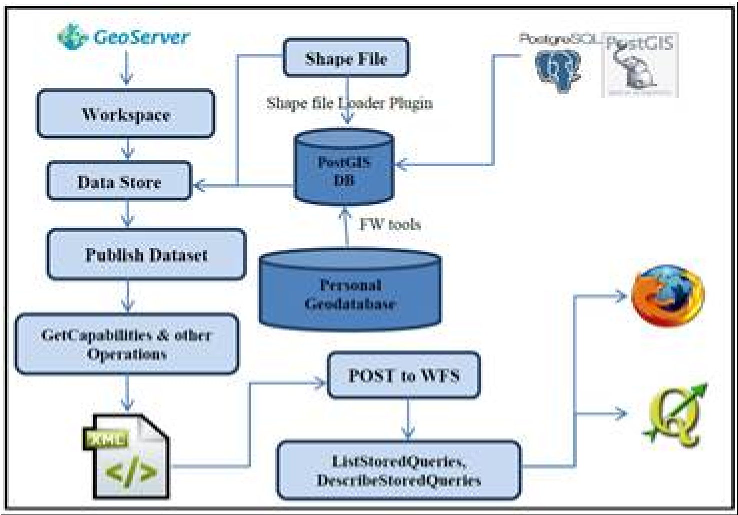

Figure 2: Detail Workflow for the Implementation of WFS 2.0 including Stored Query

From the GetCapabilities document it is important to know the necessary information about the service capabilities like the supported requests methods for available operation to retrieve features, available comparison operators to create stored query and other necessary information. After creation of WFS 2.0 the necessary conformance classes has been checked and analyzed for the evaluation of the current prototype SDI.

3.3 Stored Query Creation

After getting the necessary information from the service capabilities document, it is time to create the stored query based on service capabilities. With the new included operations for managing stored query inside the service, WFS 2.0 provides the basis to create or delete the stored query as well as retrieve the list and detail metadata about a stored query from the service. To create a stored query it is necessary to create a XML request based on CreateStoredQuery operation (see figure below) and send it to WFS through HTTP POST method. The current study created a few stored

[1] http://localhost:8080/geoserver/Asraf/wfs?service=WFS&version=2.0.0&request=GetCapabilities

query based on different comparison operators and also has tested those queries in both web and software client.

```
<?xml version="1.0" encoding="UTF-8"?>
<wfs:CreateStoredQuery service="WFS" version="2.0.0"
xmlns="http://www.opengis.net/wfs/2.0"
xmlns:wfs="http://www.opengis.net/wfs/2.0"
xmlns:ows="http://www.opengis.net/ows/1.1"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:fes="http://www.opengis.net/fes/2.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:Asraf="http://localhost:8080/geoserver/Asraf"
xsi:schemaLocation="http://www.opengis.net/wfs/2.0
http://schemas.opengis.net/wfs/2.0/wfs.xsd
http://www.opengis.net/gml/3.2
http://schemas.opengis.net/gml/3.2.1/gml.xsd
http://localhost:8080/geoserver/schemas/gml/3.2.1/gml.xsd"
xmlns:ns1="http://www.opengis.net/ows/1.1">
<wfs:StoredQueryDefinition id="BuildingUseArea">
<Title>Building Use Query</Title>
<wfs:Parameter name="use" type="xsd:string"/>
<wfs:Parameter name="area" type="xsd:double"/>
<wfs:QueryExpressionText returnFeatureTypes="Asraf:Buildings"
language="urn:ogc:def:queryLanguage:OGC-WFS::WFS_QueryExpression">
<wfs:Query typeNames="Asraf:Buildings">
<fes:Filter>
<fes:PropertyIsEqualTo>
<fes:ValueReference>NUTZUNG</fes:ValueReference>
<fes:Literal>${use}</fes:Literal>
</fes:PropertyIsEqualTo>
</fes:Filter>
<fes:Filter>
<fes:PropertyIsGreaterThan>
<fes:ValueReference>Shape_Area</fes:ValueReference>
<fes:Literal>${area}</fes:Literal>
</fes:PropertyIsGreaterThan>
</fes:Filter>
</wfs:Query>
</wfs:QueryExpressionText>
</wfs:StoredQueryDefinition>
</wfs:CreateStoredQuery>
```

Figure 3: Request example for creating stored query

The above request can be divided into different important parts to understand the basic concept. First of all it defines the xml and encoding system as in general xml documents. Then the xml namespaces parts defines the necessary xml namespaces related to this request like the namespaces for wfs, ows, gml, fes, xsi, xsd as well as the workspace name of dataset stored in geo server which is called here in this document as "Asraf". Then the schema location part defines the required locations of the related important schemas to create this request. Then it comes the definition of identification of the stored query, type of parameter used in filter function as well as the language of the query expression and supported feature class definition. Then in the filter section, it is important to add different filter function to make query strong and precise.

It is important to know that more than one property name to filter dataset using different comparison operator is possible to use in creating a stored query request. It makes the query more specific to get more precise feature collection. In this current query request two different comparison operators named PropertyIsEqualTo and PropertyIsGreaterThan for two different property names have been used to filter dataset to get a precise feature collection using different property of the feature class. Here, the first comparison operator will search for the Building features based on the valid values of property name NUTZUNG or use while the second comparison operator named PropertyIsGreaterThan will select then the features with an area larger that the user defined area value from selected features with NUTZUNG value. After setting all the required parameters and other necessary information, the request was then sent via HTTP POST method using Firefox Poster plugin to the following URL: http://localhost:8080/geoserver/Asraf/wfs

Then the stored query has been tested both in Web browsers and with QGIS WFS 2.0 Plugin in the QGIS environment.

4 Results and Evaluation of SDI Download Services

4.1 Predefined Spatial Data Download Service through Stored Query

Stored query can retrieve predefined dataset stored in the server. The predefined dataset in this study like "Buildings" from the Cadastral Information of Jagstfeld area were stored in the server published through WFS 2.0. The present study has created a few numbers of stored queries. Among them Building Use Query allows users to get the Building features based on the property value "NUTZUNG" or the purpose of the Building which means the building features are for living, garage, schools or other public or private use. The feature information can be retrieved through a GetFeature request based on stored query ID and other necessary filter parameter about the stored query. The study has tested the stored query both in web browser like Google Chrome or Firefox as well as connected it in QGIS using the newly developed plugin named QGIS WFS 2.0 Plugin.

In the web browser to retrieve features via WFS 2.0 based on the stored query ID will return an xml document with the spatial, attributive and other schematic information about the feature after sending a valid request. Following is an example of retrieving features through Building Use Stored Query from the current prototype SDI.

```
http://localhost:8080/geoserver/wfs?service=WFS&request=GetFeature&version=2.0.0&St
oredQuery_ID=BuildingUse&use=Wohnhaus
```

QGIS WFS 2.0 plugin can easily download features through Stored Query. After putting the valid URL of the service it is just needed to choose the right options like List Stored Queries, and then it will show the list of stored queries running in the server. Then by choosing the stored query named BuildingUse or others from the list and putting valid values in the parameter fields, it will then ask for CRS to present the feature in the required CRS in the QGIS environment. This transformation is done by the software environment. Then at the time of presenting any features with another CRS, the software asks for the required CRS to present the geographic data on data source CRS. Then after the required processing the plugin will download the dataset based on the stored query in the QGIS environment for further spatial analysis or editing (Figure 4.1). The figure 4.1 shows the downloaded building features of 'Wohnhaus (Living)' purpose, where in the legend it is showing the stored query ID instead of building purpose property value 'Wohnhaus' or feature class name. This is an issue using this plugin which is discussed critically in the section Critical Issues later in this report. In this way it is possible to download other building features with different purpose like 'Garage', Schools and so on as shown in Figure 4.1

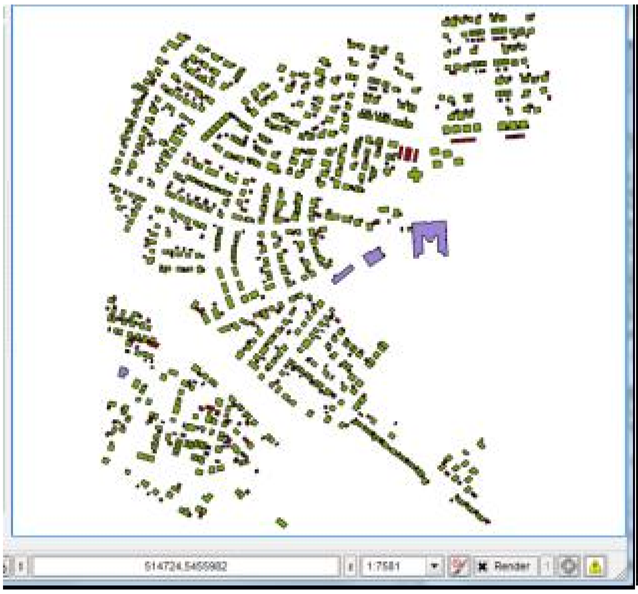

Figure 4.1: Feature selection through Stored Query in QGIS

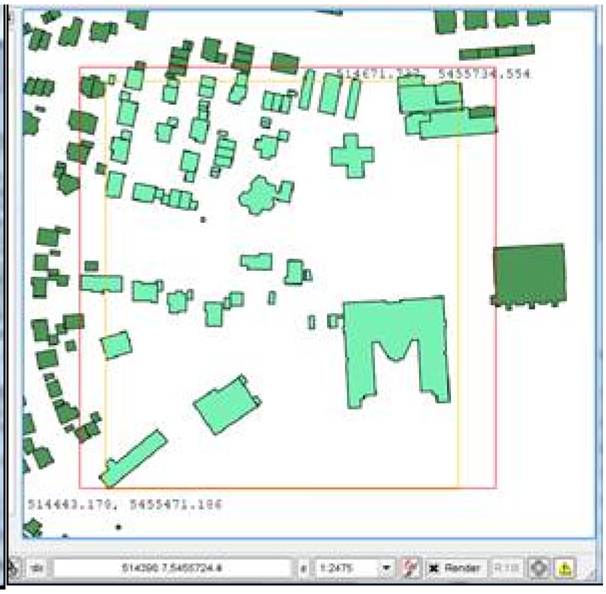

Figure 4.2: Feature Selection through Bounding Box (BBOX) Query in QGIS

Another stored query created in this research can download more precise features using the building use and area parameter. Another query download the features based on a BBOX or bounding box (Fig: 5).

4.2 Critical Issues about Stored Query Functionality

There are some critical issues in the Stored Query functionality. The first issue is about the use of workspace namespaces in the service request URL. That means if the Geoserver workspace name is used in the request URL of the GetFeature request via stored query, it will give a java Null Pointer Exception (NPE) error. It means with workspace name the stored query cannot find the exact location where the features uploaded in the server through WFS 2.0. This issue was still an unsolved issue in Geo Server issue tracker. But in my point of view, the problem is the location of Stored Query inside the geo server data directory. After creating a stored query, it stored inside the "wfs" directory inside the geo server data directory and not inside the workspace name directory. So, when the requests are sent using the Workspace name, it became unable to find anything inside that specific folder. Another issue is QGIS plugin retrieves the feature class based on the stored query the plugin is unable to define the type name of the feature class. It defines features as Stored Query ID in every return in the legend (Figure 4.1). Later on it has to be modified for further analysis. Another issue is related to the BBOX query that returns a feature collection within a bigger bbox than given parameter value which has already been shown in Figure 4.2 as well as discussed in the previous section in detail. When these issues will be solved the Stored Query will become more functional and easier to use for downloading and analyzing geographic features using interoperability.

4.3 Direct Access Data Download Service via WFS 2.0

Direct access download service allows access to the whole database stored in the server through HTTP protocol. It allows filter as well as query functions to request different information from the service based on the query expressions. To implement the direct access download service, the service must comply with the conformance classes specified by the OGC WFS 2.0 standard, 2010. According to the ISO 19142 OGC Web Feature Service 2.0 and ISO 19143 OCG Filter Encoding 2.0 standard those conformance classes are the following:

Basic WFS

Ad hoc Query

Resource Identification

Minimum Standard Filter

Minimum Spatial Filter

Minimum Temporal Filter

The prototype SDI has been developed and tested according to the above mentioned OGC specified conformance tests for the quality assurance of the service implementation. Figure 4.3 shows the operation metadata section of the service where it fulfills the Basic WFS conformance class.

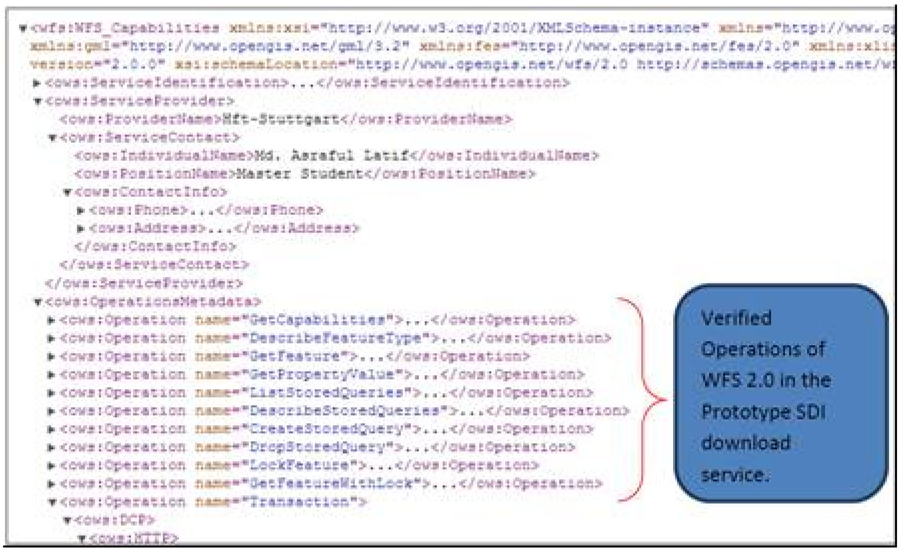

Figure 5: Conformance to "Basic WFS"

Ad hoc query is a general query expression to retrieve features based on different spatial or attributive query. To check this conformance class a simple KVP encoded request can be sent to the service like the following:

```
http://localhost:8080/geoserver/wfs?service=WFS&request=GetFeature&version=2.0.0&ty
peName=Asraf:Buildings&count=2
```

It retrieves an xml document with the matched parameter for the required feature. From the GetCapabilities response document the resource identification class can be confirmed as shown in figure 6:

Figure 6: Capabilities document showing Id_Capabilities

By sending the following request the spatial filter conformance class can be tested. The returned document must show the feature within the BBOX.

```
http://localhost:8080/geoserver/wfs?service=WFS&request=GetFeature&version=2.0.0&ty
peName=Asraf:Buildings&BBOX=514443.178,5455471.186,514671.737,5455734.554
```

There is big problem with Bounding Box feature selection in WFS 2.0 which has already been discussed in the critical issues of Stored Query results in this report. This issue is same as in the case of Stored Query based on Bounding Box that the service selects the features which are on the line of Bounding box instead of selecting features totally within the BBOX. For this it returns the coordinates of a bigger BBOX than in the request.

4.4 Pros and Cons of Data Download Service

There are benefits as well as few disadvantages in the spatial data download service based Stored Query and direct access via WFS 2.0. Stored Query is a predefined query runs inside the service allowing download of predefined dataset based on the stored query parameter. In the case of both stored query and direct access the data and stored queries are fully controlled and maintained by the owner. Stored Query can be created easily by sending valid POST request. On the other hand direct access allows users to request datasets from the server directly by their own choice of query or filter function. It provides the basis for controlling as well as filtering or limiting the feature information on the client side. According to the conformance classes, it allows better flexibility in the data sharing as well as geospatial analysis through direct access via WFS 2.0 over the web. Different types of filter functionality can be implemented by this service using SQL query using the PostGIS database in the server. The requests are very easy to send using XML, KVP or SOAP encoding system.

As disadvantage both has some critical issues like Java Bull Pointer Exception (NPE) error and downloading features in QGIS environment issues are already explained in previous section of Critical Issues about Stored Query Functionality. Also at the moment only QGIS WFS 2.0 plugin is available to support the stored query and direct access via WFS 2.0.

5 Conclusion

A perfect SDI establishment depends on the best policies, technologies that are used to implement it. New ideas and technologies can improve SDI functionality to serve the people in near future. INSPIRE requested methods to implement spatial data download service is also a better idea by adding predefined dataset download possibilities to control and maintain dataset in the server side. Geo server supports almost all the requirements of INSPIRE regulated rules for downloading predefined dataset as well as direct access via WFS 2.0. But there are some issues related to INSPIRE download service technology like workspace namespace for Stored Query, language supports in INSPIRE extended capabilities extension in Geo Server, etc. These problems will be solved in near future as Geo server is improving itself rapidly with the contribution of many programmers.

Geo server is free server software which is very useful to implement SDI for any organization in low installation cost and also QGIS can be used without any cost as a software client to connect the web services through its interoperability system. This paper described the use of Geo server and QGIS as the main tool to implement as well as test the prototype SDI download service based on the INSPIRE regulated possibilities to implement predefined dataset download service and direct access data download service. Here we gave an overview on the evaluation of the SDI download services as well as explanation on the point of view of cost effectiveness, installation complexity, supported software availability, advantages and disadvantages of the services, different relevant issues about the web services along with server software and so on.

Future scope of the current study would be to implement an SDI in the university server to use for both academic and other future professional purpose. In this way the necessary geographical data can be shared among the university students along with the professors or other stuffs to use it for academic or for any other projects. This will also be helpful for any government or private organizations in the developing countries to establish SDI to store share and analyze their geographic data centrally at a very low cost using free and open source software and server.

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Application of Geospatial Technologies for Agricultural and Climatic Studies: A case Study of Taita Hills, Kenya

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KEY WORDS: GIS, GPS, Geospatial, Land use, Land cover, Modelling, Agro-ecology

ABSTRACT

Climate variations all over the world have huge potential impacts to the environment at large. Human and economic activities are not left behind when climate change issues are concerned. Agriculture, being the core human and one of the basic economic activity is severely hampered by climate variations. In Africa, and specifically in Kenya, there has been rampant change in the growing patterns of some crops. Farmers lack knowledge that ascertain the reason behind the low income from their farm produce. Unfortunately, assessments of climate change are often limited to mean temperature and precipitation. Knowledge of changes in extremes is sparse, particularly for Africa. The need for application of more and precise spatial data for such studies arises. This study employs hyperspectral AISA Eagle VNIR imagery acquired with 9 nm spectral and 0.6 m spatial resolutions over a spectral range of 400 nm to 1000 nm. We achieved an overall accuracy of 77% with a kappa value of 0.67 in identifying crops in Taita Hills. Moreover, it shows the development of Agro-ecological Zones for Taita Hills in Kenya from a GIS point of view and develops a model of its variation given that climate is varying over a period of time. It gives a prediction for the variation of the zones based on climate change in the year 2050. Geospatial data and technologies are great tools for analysing climate variations and its impacts on agriculture.

1 Introduction

1.1 Overview of Hyperspectral Remote Sensing

Hyperspectral remote sensing data can provide a significant spectral measurement capability over the conventional remote sensor systems and hence becomes very useful in identification and modelling of terrestrial ecosystem characteristics. Not long ago, mapping was mainly using satellite (space borne) data for large area mapping but for small regions, it used aerial images and in most cases, the result was just a land cover map combining several classes of pixels having some broad similarity. The need to discriminate crop species to know their health, location and distribution has paved way in this decade due to available sensors which can detect at high spatial and spectral resolutions the natural and man-made features on the surface of the earth. The advancement not only on the sensor availability but also the technology used to discriminate the various spectra of different species has become a boost to mapping. Many technologies have been used for extracting terrestrial features from hyperspectral imagery. Principal component analysis (PCA) among other algorithms for crop classification has yielded good results. Step-wise discriminant analysis (SDA) and derivative greenish vegetation indices (DGVI) to classify and characterize both vegetation and agricultural crops have been used. Dissimilarity based approaches have also given good representation of hyperspectral data. Tree species identification has been one area of interests for scientist dealing with forests and vegetation mapping. Statistical methods to identify tree species in forests have shown good and accurate results. Nevertheless, Artificial Neural Networks (ANN) and Linear discriminant analysis (LDA) have given reliable results in tree species identification.

1.2 Overview of Agro-ecological Zones (AEZ)

An AEZ is defined as that geographical unit with similar land resource potential and limitations related to agriculture. Although there is the uncertainty in delineating the boundary between two consecutive zones, using several approaches such as: Fuzzy theory, wavelet analysis and geographical clustering, there is no single method that has been deemed to be the best. GIS on the other part has tremendously improved the processing and visualization of AEZ. Multivariate clustering has given good results in other fields such as geology, constant fertility, uniform regions for crops and many more. It is a very useful tool for assessment of land resources for better planning and management and monitoring of these resources. AEZ can be used in various assessment applications, including: Land resource inventory; inventory of land utilization types and production systems, including indigenous systems, and their requirements; potential yield calculation; land suitability and land productivity evaluation; forestry and livestock productivity; estimation of arable areas; mapping agro-climatic zones, quantitative estimates on potential crop areas, yields and production; land degradation assessment, population supporting capacity assessment and land use optimization modelling; assessing and mapping flood and drought damages to crops; assessment of impact of climate change; monitoring land resources development among many other applications.

1.3 Objectives

The objectives of this study were (1) to evaluate the spectral angle divergence of various crops in discriminating crop species and to assess the accuracy of the classification (2) to come up with AEZ that predicts the future change scenarios using biophysical data (soils, slope, land use and aspect) with the combination of the changing parameters of climate data (temperature and precipitation) amd (3) to assess the impacts of AEZ changes given that there will be a change in the year 2050.

2 Materials and Methods

2.1 Study Area

Taita Hills, (03°20'S, 38°15'E) in Kenya are one of the biodiversity hot spot in Eastern Africa. A wide range of studies have been made recently in this area for instance, on land use, land degradation, soil erosion, biodiversity, urban growth and sacred forest remnants. The area is facing a population growth and intensification of agriculture, which is the major economic activity for the Taita community. Although the terrain varies from 600 m to about 2200 m.a.s.l, farmers cultivate various crops ranging from maize (Zea mays), bananas (Musa paradisiaca), fruits and even fodder crops for animals, which are normally put in zero-grazing system.

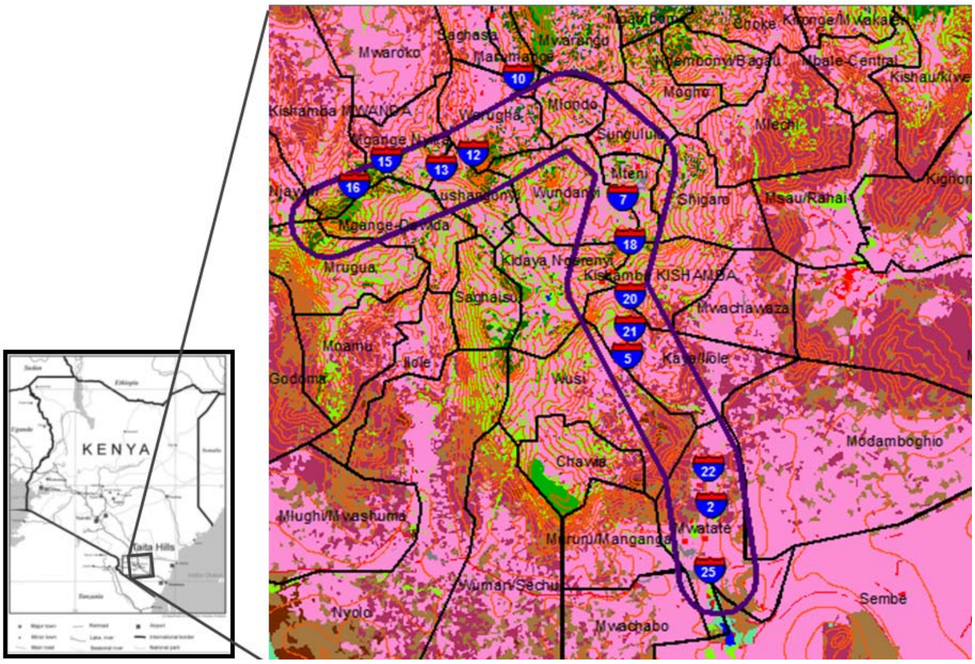


Figure 1: Taita Hills shown on a classified SPOT image of 2003. The buffered blue line is the transect area whereas the blued numbered dots inside it are the sample plots that were used as training samples.

2.2 Hyperspectral Data

Hyperspectral data was collected using AISA Eagle VNIR sensor system. Its accuracy is ranging in the following domain: 9 nm and 0.6 m in both spectral and spatial resolutions respectively over a spectral range of 400 nm to 1000 nm. This gives 64 spectral bands. The fieldwork measurements were conducted simultaneously with hyperspectral data acquisition. The flying height was about 2,400 mean above sea level. Accurate photographs taken by the Nikon 3DX camera, which was attached together with the AISA sensor on board during the time of flight, were used to map every species in the selected plots. This data were used as ground truth and training data. Spectral signatures of crops are known to vary due to leaf optical properties, leaf angles and spatial distribution. Signatures also vary from leaf to canopy scales. The spatial resolution for this datasets was kept at 0.6 meters, which is more accurate in discriminating the various crops especially for areas such as maize plantations, banana farms, and large fruits trees such as mangoes and avocadoes. Eight sampled plots were geo-referenced in order to get exact location of the crops in the plots. A detailed aerial mosaic was used to overlay the geo-referenced maps onto it and training polygons with respect to the crops were on-screen digitized with ArcGIS 10 out of the maps. Small regions depicting the spectral patterns for the specified crop were then generated and saved as regions of interests (ROIs) and later used as endmembers.

The hyperspectral image collected was subjected for pre-processing. This catered for three distortions: radiometric, geometric and atmospheric effects. Radiometric corrected for sensor sensitivity, solar angle and topography. Geometric correction was basically applied to have a geometrically correct image. Digital elevation model at 20-meter resolution was resampled to 0.6 meter spatial resolution which conformed to the image spatial resolution. Atmospheric corrections was finally done to remove the atmospheric effects. The image was checked using the z-profile tools and spectral reflectance on every cursor location of the image was analyzed. No distortion was evident. This procedure was conducted using the ATCOR-4 software which is specifically designed for correcting for atmospheric distortions. For spectral extraction, 148 digitized polygons were used to derive endmembers for crop classification. They were extracted from the sampled plots. These comprised of maize (Zea mays), bananas (Musa paradisiaca), mangoes (Mangifera indica), avocados (Persea americana), sugarcane (Socharum spp.) and farm trees such as Cypress (Cupressus dupreziana), Grevillea (Grievillea robusta) among many others. They were further divided into two datasets so that about 30% of every class was reserved for accuracy assessment and 70% was used for classification. Theoretically, existing pure features in mixed pixels are referred to as endmembers and their collection describes all spectral variability for all pixels in a given image. Endmembers for this study were selected to enable mapping of the selected crops using spectral angle mapper (SAM) algorithm of Envi software.

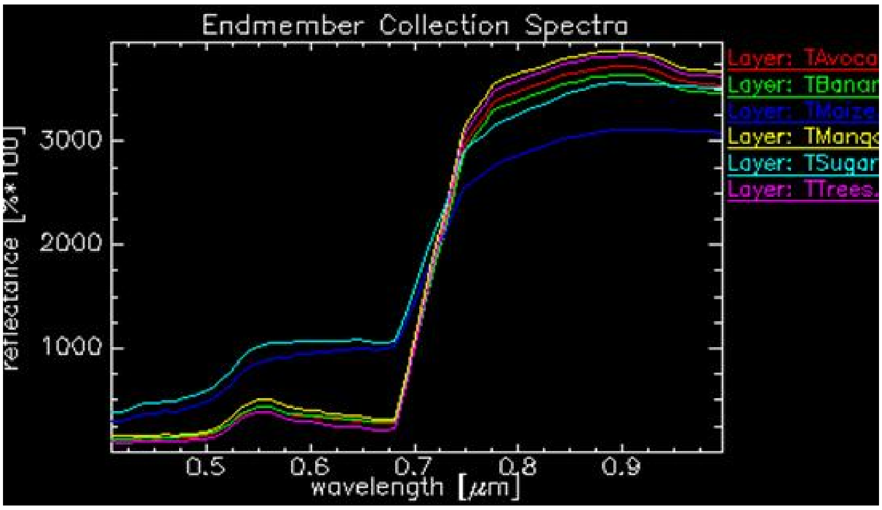


Figure 2: Spectral profiles of six endmember extracted from input image.

Figure 2 shows the spectral reflectance of the six-collected endmembers in different colors. Blue corresponds to maize plantations, cyan on the other hand corresponds to sugarcane whereas yellow is for mango trees. Magenta is representing agro-forestry, green for bananas and finally the avocados are represented by red color. Spectral Angle Mapper (SAM) is a physically-based spectral classification that uses an n-D angle to match pixels to reference spectra. It assumes that data have been reduced to apparent reflectance (true reflectance multiplied by some unknown gain factor controlled by topography and shadows). The algorithm determines the spectral similarity between two spectra by calculating the angle between them as vectors in a space with dimensionality equal to the number of bands (n). Endmember spectra used by SAM can come from ASCII files or spectral libraries, or one can extract them directly from an image (as ROI average spectra). SAM compares the angle between the endmember spectrum vector and each pixel vector in n-D space. Smaller angles represent closer matches to the reference spectrum. The result is a classification image showing the best match. Pixels further away than the specified maximum angle threshold in radians are not classified. SAM was used to classify the selected crop species in Taita hills. The spectral angle of dissimilarity was kept at 0.1 radians.

2.3 GIS Datasets

The soil data was obtained from International Livestock Research Institute (ILRI), Kenya and shows the soil physical and chemical properties. It was done by Kenya soil survey (KSS) in 1982 and revised in 1997. Very high resolution climate data such as temperature and rainfall were downloaded from 'WorldClim' data of FAO. Slope and aspect were developed from the 1:50,000 standard topographical maps for Kenya and resampled to give 20-meter accuracy (courtesy of University of Helsinki, department of geosciences). Land cover map was developed using SPOT imagery of 2003.

2.4 Historical Climate Data

Very high resolution interpolated climate data (temperature and rainfall) were downloaded from 'WorldClim' data of the FAO. These datasets are preferred for ecological modelling and GIS purposes. The spatial resolution is at 1km. These data has utilized the Global Historical Climate Network Dataset (GHCN) for the period 1950-2000 and also FAOCLIM 2.0 global climate for 1960-1990. A thin plate smoothing spline algorithm implemented in ANUSPLIN was used for interpolating these datasets. Data from the Kenya meteorological department have been collecting data for Taita hills since 1990 to 2010. Part of this data was also used in this study. Weather Station data from some selected weather stations for the year 2010 to 2012, collected by Johanna Hohental (University of Helsinki) for a similar study was used for validation. Table 1 below show the means of both temperature and precipitation (2010-2012) to validate historical data and it tallied well with 'WorldClim' data.

East	North	Elev.	Temp (˚C)	Prec. (mm)	Location
429325	9624413	1407	20.83	1390	Wundanyi
426825	9623401	1657	18.69	1460	Wesu Hospital
430248	9612549	887	24.42	984	Mwatate
429293	9619152	1114	22.42	787	Dembwa
425591	9626700	1644	19.04	1218	Werugha
427245	9614524	1625	20.44	914	Chawia
428129	9625476	1489	20.09	1378	Kitukunyi
423583	9619062	1122	22.38	1037	Bura
420496	9624927	1693	18.66	536	Mwanda

Table 1: Annual Average Temperatures and Precipitation from Weather Stations around Taita Hills (2010-2012 By Johanna Hohenthal).

The data was then masked out from the world maps to the area of study. The projection from geographic coordinates systems to Universal Transverse Mercator (UTM) was done. Climate data was converted from raster to point data and data were interpolated to 100 meter grid resolution using inverse distance weighting (IDW). At this point, it is good to note that this doesn't improve the accuracy but rather puts more points on a given area. The same method was applied for future climate. Inter-governmental Panel on Climate Change (IPCC) have projected world climate datasets for the year 2050 which have been calibrated and statistically downscaled using 'WorldClim' data. These datasets were used to get an overview of the future scenario and compare with the current situation.

2.5 Principal Component Analysis (PCA)

PCA is a standard statistical technique that can be used to reduce the dimensionality of a data set. It is known as Karhunen-Loeve transform, has proven to be an exceedingly useful tool for dimensionality reduction of multivariate data with many application areas in image analysis, pattern recognition and appearance-based visual recognition, data compression, time series prediction, and analysis of biological data among many other applications. The strength of PCA for data analysis comes from its efficient computational mechanism, the fact that it is well understood, and from its general applicability. PCA is a method of transforming the initial data set represented by vector samples into a new set of vector samples with derived dimensions. The basic idea can be described as follows: A set of m-dimensional vector samples X = {x1, x2, x3, ..., xm} should be transformed into another set Y = {y1, y2, ..., ym} of the same dimensionality, but y-s have the properties that most of their information content is stored in the first few dimensions. So, we can reduce the data set to a smaller number of dimensions with low information loss.

The transformation is based on the assumption that high information corresponds to high variance. If we want to reduce a set of input dimensions X to a single dimension Y , we should transform X into Y as a matrix computation:[Y] = [A•X] choosing A such that Y has the largest variance possible for a given data set. The single dimension Y obtained in this transformation is called the first principal component. This component is an axis in the direction of maximum variance. The first principal component minimizes the distance of the sum of squares between data points and their projections on the component axis. PCA in this study was used for some data such as soils, slope aspect and land use but not on temperature and precipitation that were the main parameters for change.

2.6 Multivariate Clustering Analysis

Multivariate clustering analysis represents a relatively recent development, characterizing discontinuities into subsets according to multiple parameters, such as orientation, spacing, and roughness, where rather than considering one variable at a time, a number of parameters can be treated simultaneously, so that the interactions between parameters are taken into account. Several investigators have recognized the potential of geographic multivariate clustering for delineating homogeneous regions objectively within small maps. Multiple geographic areas can be classified into a single common set of quantitative eco-regions to provide a basis for comparison, or maps of a single area through time, can be classified to portray climatic or environmental changes geographically in terms of current conditions. This tool has also been widely used in delineating ecosystems regions, environmental management, water resource planning and decisions.

3 Results and Discussions:

3.1 Crop Species Classification

Spectral map relates to the spectrum that is generated from the end members selected. After classification, the classified map was linked to the color infra-red image that was used to extract the spectra. A visual analysis was done. Most of the features were classified such as maize plantations, trees and sugarcane. The color representation of the data was similar to the color scheme in Figure 2. Accuracy assessment gave an overall accuracy of 77% and kappa of 0.67. Table 2 shows the contingency matrix. The values are the number of pixels classified in every class from the total pixels that were used in the classification process.

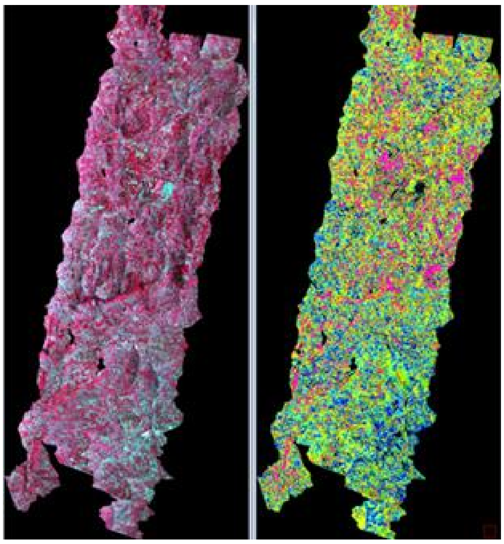


Figure 3: Original Hyperspectral Image and Classified Image Scenes.

Many pixels though are seen to be unclassified, indicated on the table 2 above as others. Producer's and user's accuracies were also tabulated, (Table 3). The trees and avocadoes were poorly classified in the final map. Trees had some similar spectra to some crops, and the major crop here was the avocado. This ended up with a misclassification of avocado species for trees. The selection of tree samples was achieved from forest patches from aerial mosaic in which there exists various species of trees. There is a high correlation between the producer of the classification and the user of the classified map in that the difference between them is less than 10 percent.

Reference (Polygons)								
Classified Map	Others	Trees	Avocado	Banana	Maize	Mango	Sugar	Total
Others	78	0	0	0	0	0	0	78
Trees	0	0	6	2	0	0	0	8
Avocado	0	1	0	3	0	0	0	5
Banana	0	1	0	4	0	3	0	8
Maize	0	0	0	0	5	0	5	10
Mango	0	3	1	0	0	23	0	26
Sugar	0	0	0	0	4	2	7	13
Total	78	5	7	9	9	28	12	148

Table 2: Confusion matrix of the classification

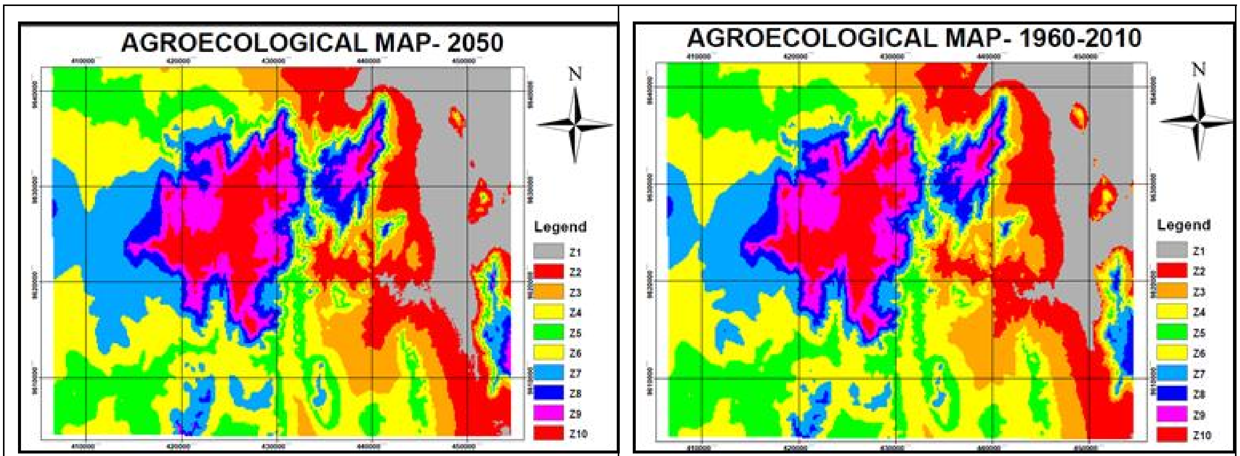
Classes	producer's	User's
Trees	0.5%	0.3%
Avocadoes	6.80%	8.4%
Bananas	49%	43.2%
Maize	50.1%	42.8%
Mangoes	78.7%	87.3%
Sugarcane	52.4%	49.6%
Others	99.9%	99.4%

Table 3: Producer's and user's accuracies

Crop type classification indicates that it is possible to discriminate various crops using AISA Eagle VNIR data and the spectral angle mapper (SAM) algorithm in a cultivated landscape. The confusion matrix shows that most classes were classified to be trees due to the spectral angle between them being as closest. Bananas, avocadoes, mangoes and trees (call this cluster 1) had very similar profile. A distinction between maize and sugarcane (call this cluster 2) is much better than that of cluster 1. Spectral range between 500nm to 700nm can be seen to separate not only the two clusters but also the different crop types. The unclassified pixels (others) constituted mainly reflective natural and man-made features such as buildings, roads and water bodies. These were not considered for endmember selection but the pixels are part of the input image for classification. Table 3 shows the producer's and user's accuracies. Mangoes, sugarcane, maize and bananas had good producer's and user's accuracies. Avocadoes were poorly classified even though it was the class with most endmembers (see Table 1). The reason could be linked to their close reflectance with other trees. One disadvantage endured in this study is the limitation to distinguish the trees in crop land. Trees here were summation of several species from the agro-forestry areas. It can be argued that just as crops differ in their reflectance from crop to crop, it is also true that there's a reflectance difference between tree to tree and that crop types such as mangoes and avocadoes are also trees in their nature. In identifying crop types in a cultivation landscape, it is wise to identify various tree species within the agro-forestry environment too.

3.2 Agro - Ecological Zone Maps

Principal component analysis was run for soil, land use, aspect and slope (GIS datasets) but not for temperature and rainfall (climate datasets) which were the main parameters of change over time. With the initial iteration of 5 zones (which already FAO provided in 1993 for whole of Kenya) the result was coarser for analysis although it had a huge similarity to it. A new iteration was ran for 10 AEZ which gave good result to analyze and assess. Increasing the number of zones to 15 created more 'thin layer-like' zones that were difficult to analyze and assess. This procedure was done also for the future datasets (2050) with the varying parameters only being those of climate datasets. Figure 1 and Figure 2 shows the results for zones (Z1, Z2,........Z10) as per the legend. Zone delineation was possible with the use of multivariate clustering in conjunction with the principal component analysis. The zones represented for the current data and the future data did not show a huge difference in their spatial location and pattern.



a)	b)

Figure 4: Agro-Ecological Maps (1960-2010) and (2050)

The shapes of zones had a similar characteristic. To analyze for a discrepancy (shift in zones), it prompted the need to subtract the zones by what is defined as 'image zone differencing' as illustrated in Figure 5 below where Figure 4a was subtracted from Figure 4b (aggregated changes of all zones) that is to say {future zones - current zones}.

3.3 Zone Difference Maps

The legend on Figure 5 shows the values from (-3, -2, -1, 0 +1 and +2). Zones that had an increase are shown on the legend with positive values (+) whereas those with decrease are shown with the negative values (-). The generated map of the changes can be used as a model for 'zone shift' analysis in the year 2050. Some zones will in the future will reduce while others will increase. For instance, in the lower zone, where on Figure 5, we have green-colored strips, this are the (-1) values meaning there will be a reduction in zone 1, zone 2 and zone 3. On the other hand where we have blue strips on the right hand side of the same figure, the values are (+1) meaning in 2050, some of the upper zones will increase in size. Evidently seen for zone 7 in both Figures 4 and Figure 5. Zero value meant no change in the future.

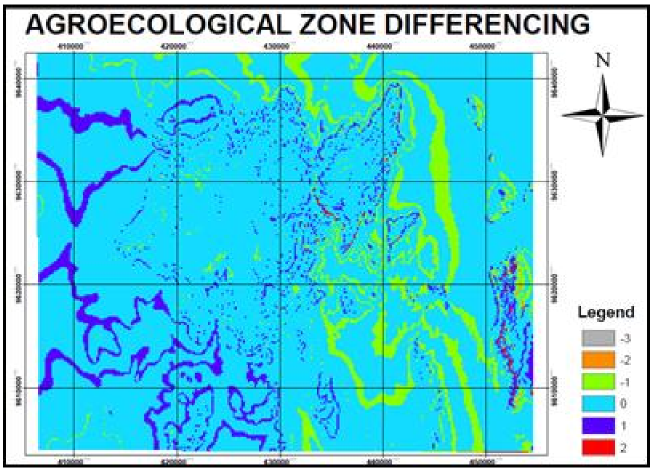


Figure 5: Zone Differenced Map (Future - Recent)

3.4 Zone Descriptions

Describing the ten zones was a bit challenging but a best description was that which followed already existing AEZ by FAO. Table 4 below shows the zones and their characteristics giving suitable crops that are grown on every zone. The validity of the crops per zone was from selected field plots located on every zone. Fieldwork was done and crops found on this plots were tabulated with a GPS measurement on every crop in every plot. These data were overlaid to the classified zones in the recent AEZ case.

Zone	Descriptor	Characteristics
Z1 - Z2	Lowlands	- Higher temperatures, low rainfall.Crops: Typically sisal.
Z3 - Z4	Upper Lowlands	-High temperatures and low rainfall. Crops: Sorghum, millet, mangoes, early maturing maize and beans.
Z5-Z6	Lower Mid-lands	- Mid temperatures, average rainfall. -Crops: Mangoes, maize, cassava, sweet potatoes.
Z7-Z8	Upper Mid-lands	-Low temperatures, above average rainfall. Crops: Bananas, avocadoes, maize, sugarcane, potatoes, tomatoes, agro-forestry.
Z9-Z10	Highlands	Lower temperatures, higher rainfall. Crops: Agro-forestry, Indigenous trees (forests).

Table 4: Zone Description and Characterization

4 Conclusions

Classification of crop types is possible using AISA Eagle VNIR data and spectral angle mapper algorithm. This study focused entirely on sampled field plots (polygons mapped from plots with respect to each crop represented therein) and spectral signatures extracted from the input airborne hyperspectral image to map out selected crops. Many studies have shown good results with this method although object based approach instead of pixel - based could yield a more accurate result. It is shown that the method of multivariate clustering in conjunction with GIS is a tool that can give precise agro-ecological zone definition. Iteration is necessary to have a good delineation of a zone hence a powerful tool to analyze regions of the same climate variation in any given region and even quantify them so that the general public are informed. The government and the stakeholders on the other hand can find ways of helping farmers maintain their farm produce and still earn a living from it. Mixed farming such as crop cultivation coupled with zero-grazing or fish farming would improve the farmers livelihood even with the variation of climate. It is meaningful to state that climate projections are based on physical models which are better at forecasting mean values of rainfall and temperature than their extremes. It follows that the impacts forecasted for the future represent averages of values which can sometimes strongly fluctuate from one year to another. Beyond this date (2050), and until 2100, a huge disparity exists between the scenarios because of uncertainties related to the quantities of greenhouse gases which will be actually emitted into the atmosphere, the dynamics of the agricultural sector and the agriculture's adaptive capacity especially in Africa.

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Design and Implementation of an Institutional geodatabse and Web GIS for European Carribean Association

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KEY WORDS: Web GIS, geodatabase, European Caribbean Association, PostgreSQL/PostGIS, OpenGeo Suite Desktop GIS software, web map application

ABSTRACT

The merging of internet and Web has created many disciplines and Web GIS is one these disciplines which is effectively dealing with the geospatial data in a proficient way. Web GIS technologies have provided an easy accessing and sharing of geospatial data over the internet. However, there a single platform for easy and multiple access of the data lacks for the European Caribbean Association (Europaische Karibische Gesselschaft - EKG) to assist their members and other research community. The technique presented in this paper deals with designing of a geodatabase using PostgreSQL/PostGIS as an object oriented relational database management system (ORDBMS) for competent dissemination and management of spatial data and Web GIS by using OpenGeo Suite for the fast sharing and distribution of the data over the internet. The characteristics of the required design for the geodatabase have been studied and a specific methodology is given for the purpose of designing the Web GIS. At the end, validation of this Web-based geodatabase has been performed over two Desktop GIS software and a web map application and it is discussed that the contribution has all the desired modules to expedite further research in the area as per the requirements.

1 Introduction

Every organization is required to arrange the information for its own functionality so that information represents one of the main resources of the organization. Therefore every organization has such kind of systems that deal with the management of this resource. Such a system is called the information system of the organization. The information system of an organization is a combination of human and material resources, and of organizational procedures for the collection, storage, processing and exchange of information necessary for the operational activities.

Currently European Caribbean Association is working in Venezuela and collecting spatial data. The idea behind this research work is to design a comprehensive geodatabase system to gather the entirety of data into a single platform and then implementation of this geodatabase over the Web to facilitate the members of the association as well as the local bodies and researchers in retrieval of relevant data as well as provision of an easy access in order for them to upload their own data into this geodatabase relating to their specific study areas. A geodatabase also helps in customizing storage configuration, allowing updates to spatial indices and data compression in the perspective of data management. So, a geodatabase is not like a single format, but it is a family of different formats that take advantage of true database ideas and maintain a broad variety of data types (Childs, 2009).

GIS is a computer system for capturing, storing, manipulating, querying and presentation of geospatial data. Geodatabase is a collection of geospatial data which can contain multiple point, polygon, and polyline layers along with other database tables in a single large file while a Web GIS is the representation of this geospatial data on the Web. Web GIS provides a great support to the common man to view and analyze geospatial data which was used by few elite users in the past (Agrawal & Gupta 2014). With the advancement in the Web and growth of internet, geoscientists have the additional advantage of two types of capabilities. First is the visualization of geospatial data and second is the wide accessibility of data over the whole world. Clients produce maps and charts which could be published on web by setting up a Web Server. User from any location can view and analyze the maps and charts. The two features: easy access to data and visual presentation of the data on web brought a great revolution in the field of Web GIS which alters the way of geoscientists to do their work in the near future (Alesheikh et al, 2002).

2 Literature Review

This section provides a review of the literature, about the designing of database systems as well as the approaches to implement the database and introduction of Web GIS to publish the database, by different researchers. At the end, an overview about the use of GeoServer and PostgreSQL/PostGIS as a solution for Web GIS and its implementation will also be the part of this section.

A GIS helps in valuable analysis and managing of spatial data. Singh et al. (2012) designed a web-based application for the sharing, displaying and processing of spatial data, based on MapServer as a web GIS server and PostgreSQL/PostGIS as an object oriented relational database management system. The developed application was cost effective and could allow all types of users to retrieve their data to help them in their decision making process.

Sarup & Shukla (2012) tried to find out the shortest path on the road with the help of spatial and non-spatial data using GeoServer as a web map server together with PostgreSQL/PostGIS for the Web GIS implementation. They concluded that nowadays open-source GeoServer software platform is a fully featured, cost-free solution for publishing of geographic information over web. They also concluded that it was possible to use GeoServer as an effective server without including a lot of other web applications.

Similarly, Saleh (2011) conducted his study about building Web-based GIS applications around open specifications and open source software using Geoserver and PostgreSQL/PostGIS database. He identified that PostgreSQL/PostGIS is a robust database management system and GeoServer is easy to use and has better production quality. He also pointed out that both Geoserver and PostgreSQL/PostGIS together give a best solution to make a Web application for the fast distribution, sharing, displaying and processing of spatial information.

Raghavan et al introduced a web GIS application using open source software involving spatial and non-spatial data together. A spatial database was developed with the implementation of a combination of GRASS GIS and PostgreSQL Object-Relational database into a Web based client/server environment. The theme behind that study was to provide a web-based platform for the data sharing between specialists, planning agencies, citizens, and private entities. The user needs to have only a web browser in order to get access to the spatial database through internet. As the system was developed with the help of open source software, it was easily and economically executed in a spatial database domain.

From above all literature review, it is confirmed that the combination of PostgreSQL/PostGIS along with OpenGeo Suite is the best solution for designing of geosdatabase and WebGIS in recent time.

3 Material and Method

3.1 Study Area

Aguirre is the study area that has been chosen for this project. It is a little village in Montalbán Municipality of Carabobo State. It is located at *10°12'54"N* and *68°19'45"W*. According to the National Institute of Statistics of Venezuela, the estimated population of this municipality in year 2007 was 23712 which is equal to the 1.1% of state's population. The population density of Montalbán Municipality is approximately 222 inhabitants/km^2 and the total area is equal to 107 km^2. Carabobo is one of the 23 states located in the northern part of Venezuela having co-ordinates *10.193°N* and *67.98°W*. The elevation of the state is 520 Meters (1710 ft). The area of the state is 4650 km^2 and estimated population in year 2011 was 2,245,744 inhabitants. 480 inhabitants/km^2 was the average density of the state in year 2011. The state is subdivided into 14 municipalities. Valencia is the capital of the state and main industrial center of the country (Wikipedia, the free encyclopedia).

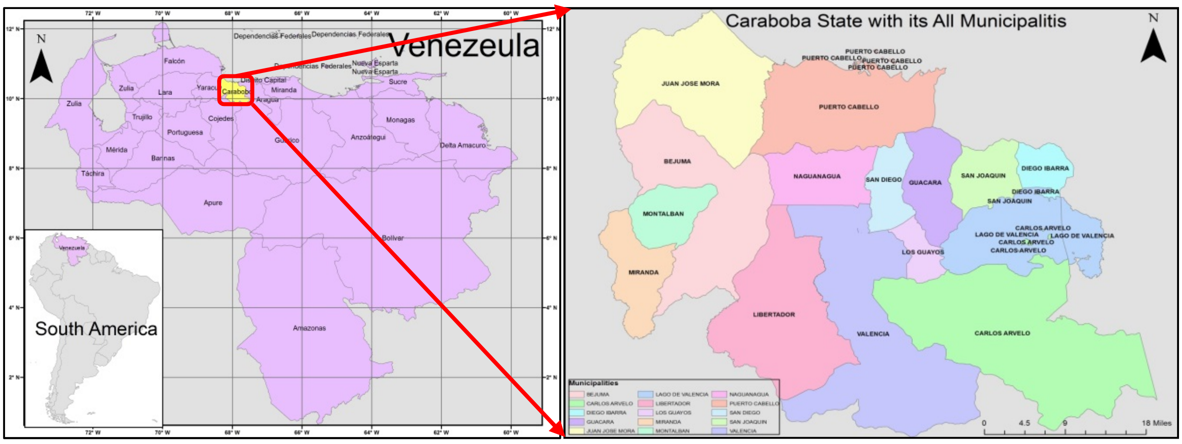

Figure 6: Study area

3.2 Methodology

Different types of methodologies can be used while designing a geodatabase. Methodology here refers to the idea of a process and the steps involved in the design of a geodatabase. It is considered a way to systematically solve a research problem. Basically it is a science that points out how research is done in an efficient way. Figure 5 illustrates the overall workflow of the project involving geodatabase designing and the physical implementation of the same geodatabase in two formats as well as the implementation in Web GIS.

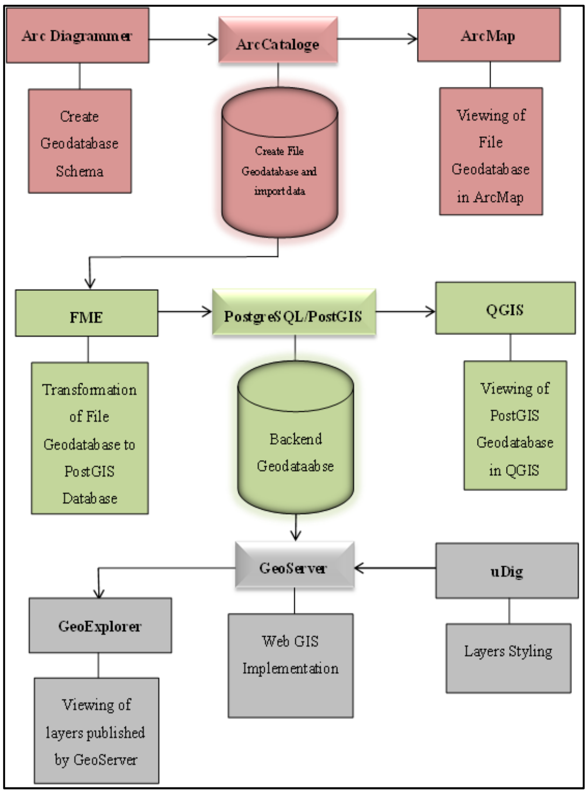

Figure 2: Steps involve in overall workflow

3.2.1 Designing of Geodatabase

Here are the three main phases of designing a Geodatabase.

Conceptual database design: In conceptual database design, a model is produced from all the required information that will be independent of all physical considerations. In this model, it is required to specify the entity types, relationship type, and the attributes related to entity type or relationship type and their domain. Then, the candidate and primary keys are determined and Entity–Relationship(ER) diagram drawn ending with a review of Local Conceptual data model with user identified functional requirements (Addison 2006).

Logical database design: Logical database design is a part of the process of database design but does not take into consideration which database system will be used, or over which hardware platform the database will be run. For the creation of relation schemas, there are some rules identifying how the ER diagram or class diagram is transferred to relation schemas. Primary and foreign keys can also be specified in this section if it is not specified in conceptual database design section. Model is, thus, validated using Normalization to eliminate redundancy and potential update anomalies. Schema is modified each time to reduce the redundancy in Normalization. At the end of this section, review Local Logical Data Model with user identified functional requirements then mapped into the DBMS dependent physical schema (Jackson, M).

In this phase ArcGIS diagrammer is used for the Schema creation from the conceptual model so that the model could be developed in detail. This phase involves the designing of the feature datasets, subtypes, behaviors and integrity rules. Total seven datasets (*Administration_Boundary, LandUse, Transportation, Public_Facilities, Institutions, Hydrology and Environment*) are modelled with their feature classes. One raster dataset is also modelled with its three bands. Subtypes and their domain values are created for some feature classes to depict the different land use.

Physical database design: Physical database design is the last stage of Geodatabase design that involves the design of the database. In this phase, it must be known which Database Management System (DBMS) is used. Afterwards the model is validated and checked for future growth. Finally draw ER diagram and review the model with user identified functional requirements (Wong 2001).

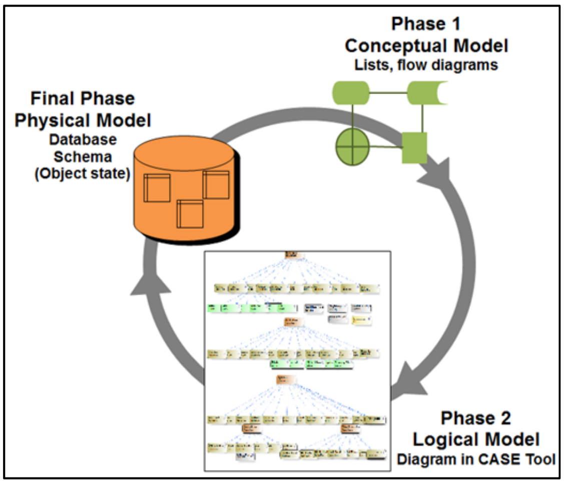

Figure 3: Phases of Database designing (source ESRI)

3.2.2 Physical Implementation

The purpose of physical modeling phase is to translate the logical geodatabase schema into targeted database systems of empty tables and integrity constraints like topologies and network. ESRI "*File Geodatabase*" and "*PostgreSQL/PostGIS*" are the targeted database systems for the implementation of logical geodatabase schema. In this section, implementation of geodatabase schema into these two targeted database systems is explained.

The schema of logical data model in then saved as "XML Workspace Document" and later on imported into "ESRI File Geodatabase". The figure below shows the imported XML schema into File Geodatabase with all its feature datasets, feature classes and relationships.

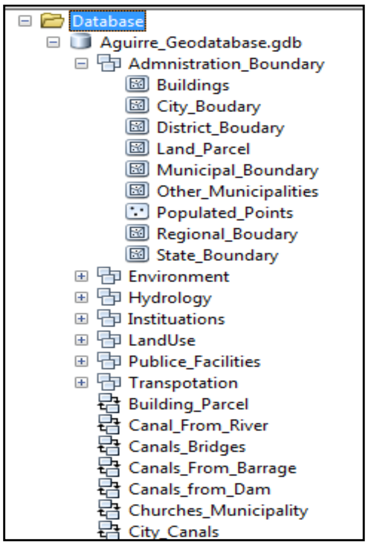

Figure 4: Implementation into File Geodatabase

After successfully Importing XML Workspace document into File Geodatabase, the next step is to load the existing data into database using ordinary data loader of ArcCataloge. Following figure will give an idea on importing data from "shapefiles" into "Aguirre_Geodatabase" using ordinary data loader tool.

3.2.3 Translation of File geodatabase into PostgreSQL/PostGIS database

For the physical implementation of logical model, PostgreSQL database is chosen. Unlike ArcGIS, PostgreSQL hasn't any ordinary data loader tool. So, data is transferred into PostgreSQL database using Feature Manipulating Engine (FME) software. FME has the ability to translate ESRI File Geodatabase to PostgreSQL/PostGIS database.

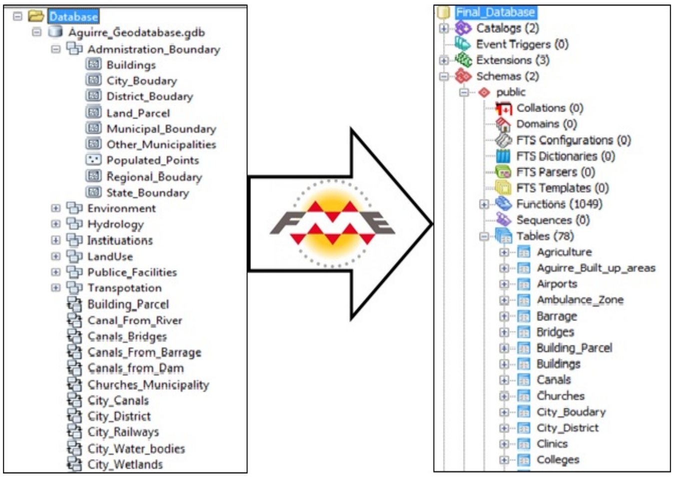

Figure 4: Transformation File Geodatabase to PostgreSQL/PostGIS database

3.3 WebGIS Design

The combination of Web and Geographic Information System (WebGIS) is one of the Geoinformation Technology fields that facilitates the widespread use and dissemination of spatial information. The basic idea of the webGIS is to visualize the spatial representation of the existing information over internet. This section explains the basic pre-requisites to design and implement geodatabase over web.

OpenGeo Suite Architecture: OpenGeo Suite is a complete open source web-based geospatial software package for managing data, as well as building maps and applications across web browsers, desktops and mobile devices. Dashboard of OpenGeo Suite appears on web browser at "*localhost:8080*".

OpenGeo suite architecture is a way of categorizing technology pieces that may be used for making a map on internet and building of existing information infrastructure. There are three phases of OpenGeo Suite architecture which are breaking internet mapping into functional layers.

- Database
- Application Server
- User Interface

On the lower part of this structure, there is the PostGIS database. Application server (GeoServer and GeoWebCatche) lies at the middle part of this structure and finally the user interface containing Geo Ext and OpenLayer for visualization is on the upper part.

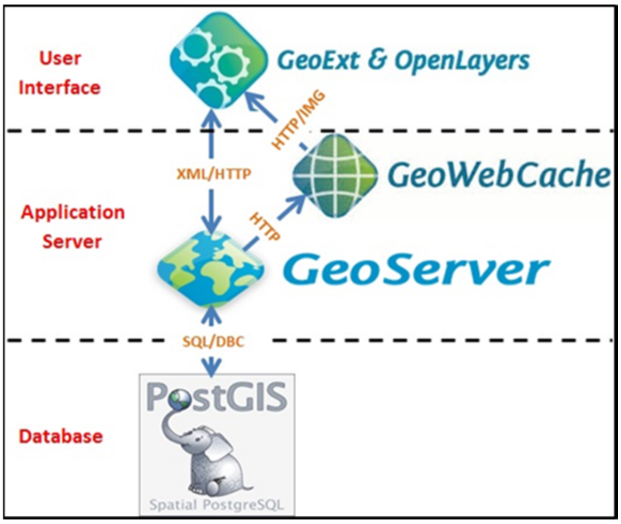

Figure 5: OpenGeo Suite Architecture

In OpenGeo suite architecture, database and application server interact via SQL (Open Geospatial Consortium Standards) and application server interacts with user interface through standard web encoding (XML, JSON, Images) over an HTTP protocol. In this architecture,

- PostGIS database is able to answer spatial queries and also standard attributed data queries.
- GeoServer is able to provide standardized web access to underlying GIS data sources.
- GeoWebCache tiles server uses standard web protocol to serve maps tiles for request and response, and also to store them intelligently.
- The function of GeoExt/ExtJS interface includes user interface (UI) and binding for spatial features specifically.

Functionality of the OpenLayers is to consume maps from different sources and to provide tools for editing and capturing data.

3.3.1 Import PostGIS databse in GeoServer

GeoServer is a component of OpenGeo Suite, launched from its Dashboard. After launching of GeoServer, the next step is to create a new "workspace". "*Opengeo*" is name of new created workspace where PostGIS data would be imported. When GeoServer is working under OpenGeo suite, the connection to the PostGIS is different as compared to ordinary GeoServer. PostgreSQL/PostGIS database work on port "5432". The parameters for the connection to PostGIS is shown in the figure below.

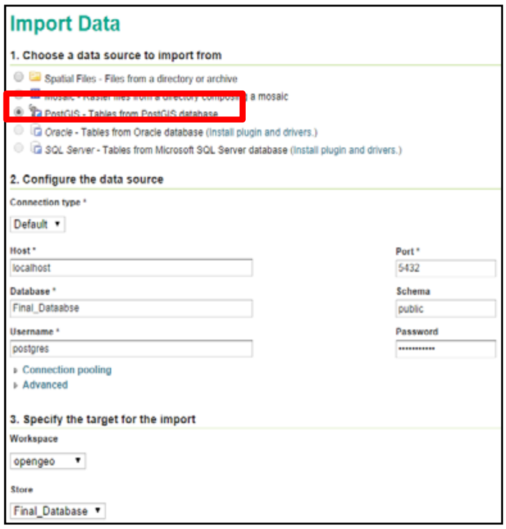

Figure 6: Importing of data from PostGIS database

3.3.2 Web Map Services (WMS) Configuration

GeoServer is used to publish PosGIS database on the web and also provides support for Open Geospatial Consortium (OGC) **Web Map Service (WMS)** versions 1.1.1 and 1.3.0. For the generation of the maps on web, these standards are used widely. It is a primary interface to request map produced in GeoServer. Clients are able to overlay maps from several different sources in a seamless way with the help of WMS. In GeoServer, configurations for the WMS are activated and tiling is specified in a 4 by 4 configuration to enable fast rendering of data. The main difference between the WMS versions in the operation of GetMap is that the SRS parameter in WMS version 1.1.1 is now changed into CRC in WMS version 1.3.0 (Geosever User Manual 2014).

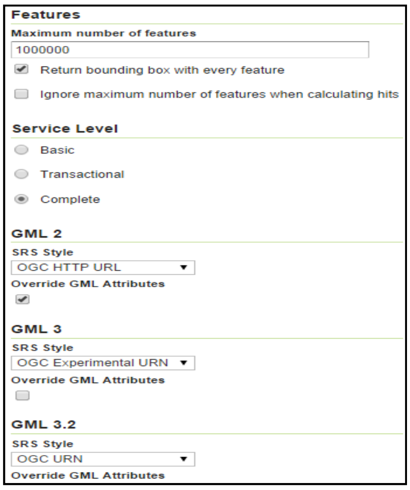

Figure 7: Basic configuration of WFS in GeoServer

3.3.3 Web Feature Services (WFS) Configuration

GeoServer has the ability to serve geographic features across the web under OGC Web Feature Services (WFS) standards. Information about the feature geometry and feature attributes is accessible through WFS. It supports the configuration of features, their service level and the output in the form of Geography Markup Language (GML) which is a modeling language for geographic features. WFS version 1.0.0 requires the use of GML version 2 which contains encoding support for basic geometric primitives like points, lines and polygons. On the other hand WFS version 1.1.0 requires the use of GML version 3.1.1 which contains enconding support for more advanced geometric representations like curves, surfaces, multi band imagery time and elevation. A basic cofiguration for the WFS services in GeoServer is shown in figure below (Geosever User Manual 2014).

4 Evaluation of Web Application

This chapter presents the results and discussion of the methodology outlined in the previous chapter. It gives suitable answers of the research questions already presented in the Introduction such as the possibility of accessing a designed geodatabase for different users over the web, accessing WMS and WFS services of the designed application and the impact of Open Source Web GIS technologies on the field of Web GIS?

4.1 Access of WMS in ArcMap

A Web Map Service (WMS) layer in ArcMap permits the display of specific geographic features with their attributes in the form of a map. It is an Open GIS standard description for interactive mapping based on request of map images from a server via Internet. ArcGIS allows accessing these services and adding them to ArcMap as a layer over the internet. A WMS defines three operations which are "*GetCapabilities*" that returns service-level metadata in the form of XML, "*GetMap*" that returns a map image whose geospatial and dimensional parameters are well-defined and "*GetFeatureInfo*" displays information about particular features visible on a map.

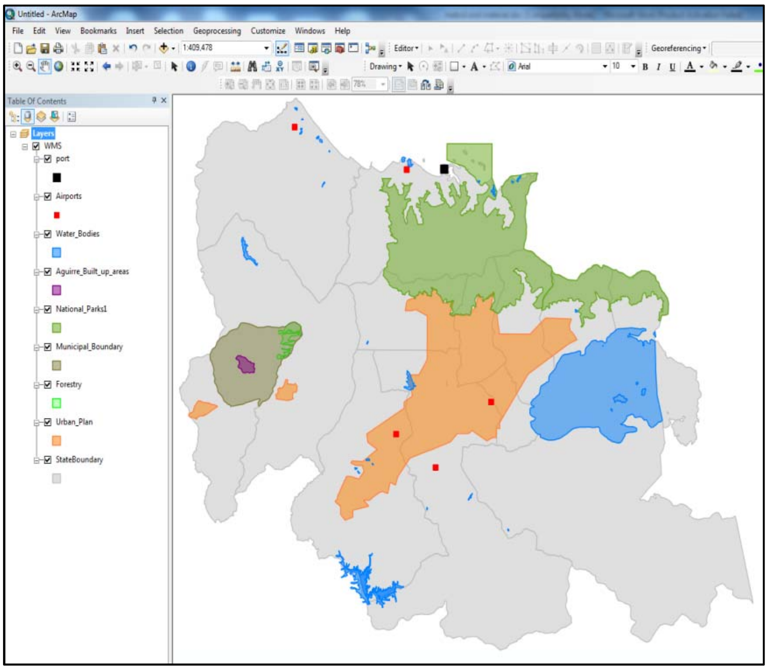

Figure 8: Visualization of WMS services in ArcMap

A WMS is a significant tool for presenting a variety of datasets in a number of web applications. It is also capable to create WMS layers in ArcMap so that the users can easily utilize data in web applications. It is a widely supported protocol for serving and querying map images and shapefiles over the Internet that are generated by a map server such as GeoServer using data from a Geodatabase. It has the capability to be integrated with other mapping solutions such as the GeoCoder and Internet Mapping Framework (IMF).

4.2 Access of WFS in ArcMap

The OGC Web Map Service permits a user to drape up map images to be displayed from served georefrenced data on one hand, while the OGC Web Feature Service allows a client to retrieve geospatial (vector) data encoded in GML from multiple Web Feature Services. WFS are standard guidelines for serving geospatial objects through the Web. Basically, WFS can perform six types of operations which are *GetCapabilities*, *DescribeFeatureType*, *GetFeatureoperations, GetGmlObject, Transaction,* and *LockFeature*. In the operation of *"GetCapabilities"* a user requests for a capabilities document from the web feature server and receives a document that contains the information about feature types (Brentjens 2004).

ArcMap has the ability to utilize WFS services as a data source for map layer. WFS have the information about features geometry and features attribute values of transported GIS features. GML is the standard language to express the information of features in WFS. In ArcMap, WFS connection is enabled through interoperability connection.

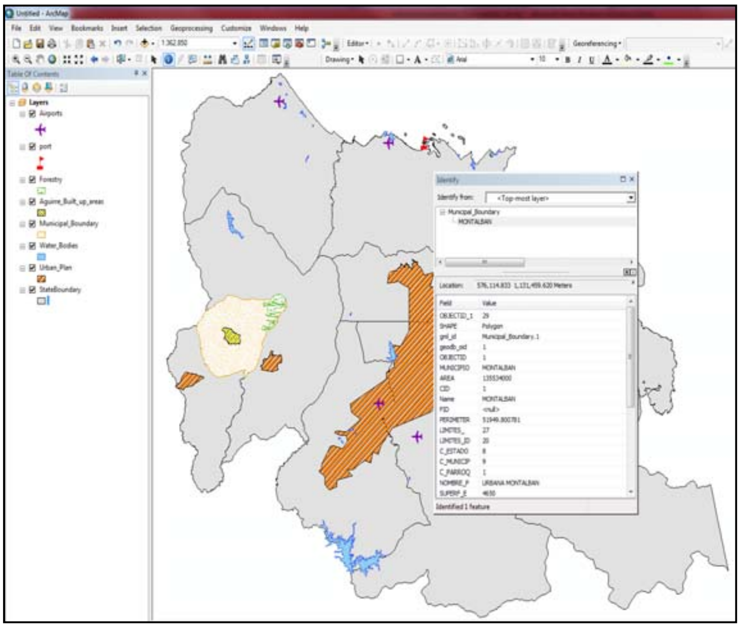

Figure 9: Geometric and Attributive information of data layer using WFS

The returned WFS response from OGC operation request produces accurate spatial data with correct number of features and their attributes. Once a WFS service layer is added in ArcMap, it is simple to work with it like other features, such as changing map display properties, identifying features, querying them and changing layer properties.

4.3 Access of WMS in QGIS

In recent times, QGIS has the capability to act as a WMS client that can understand WMS 1.1, 1.1.1 and 1.3 servers. In QGIS, a client can send a request for a raster map up to a given extent, set of layers, symbology style, and transparency by using WMS server. The server starts acting on a request and consults with local data source, recognizes the map and sends the response back usually in JPEG or PNG format. To add a WMS layer in QGIS is a very simple task, as long as the WMS server could be accessed. It is necessary to know the URL of that server and the server recognizes HTTP as a data carriage process.

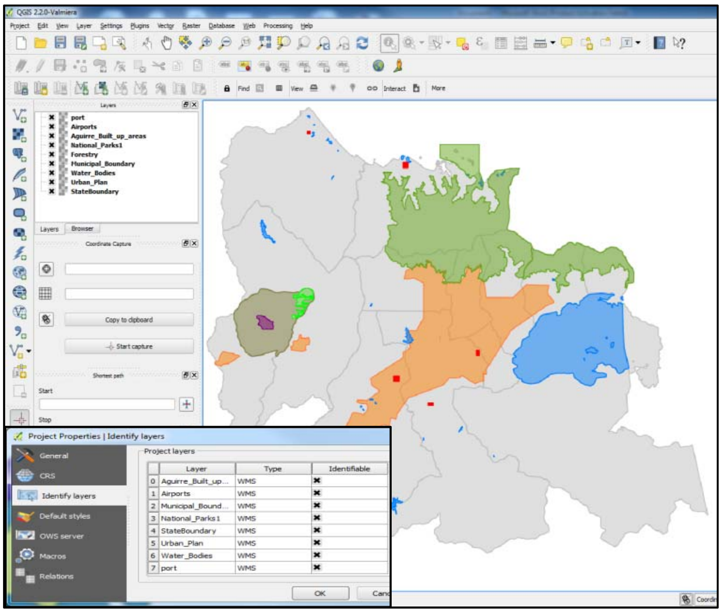

Figure 10: Visualization of WMS layers in QGIS

4.4 Access of WFS in QGIS

A WFS layer in QGIS acts as a vector layer. It is pretty simple to view the attribute tables of selected features just like the attribute table of a vector layer. The process of setting up a connection to access WFS layers from the server is similar to WMS server connection. Simply Add a WFS layer through and settings of all the remaining parameters are the same as of WMS server connection.

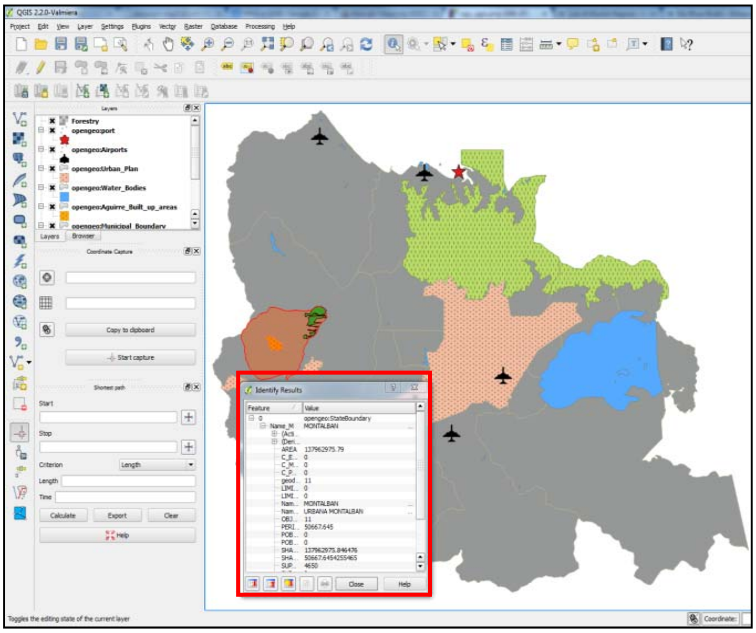

Figure 11: Geometric and Attributive information of data layer using WFS in QGIS

Figure 11 is showing the WFS data layers accessed from the server and the red box indicating here the attributive information of the layers.

4.5 GeoExplorer

GeoExplorer is a web client application of OpenGeo Suite used for composing and publishing web-mapping applications. It can be launched from the list of components on the OpenGeo Suite Dashboard. In GeoExplorer, loading of layers is done through GeoServer, and then, these could be displayed on its GUI. It provides possibility for the client to edit, query and update the data by logging in. There are three sections of user interface of GeoExplorer, which are *Main Map Panel, Button Bar* and *Layers Panel.* Navigation tools are located on Button Bar on Map Panel which permits users to zoom in and out, and pan around the maps. The Layer Panel records every layer added on the map and also provides a too-set and context menu, explaining how to interact with these layers. Overlays and Base Layers are the two groups to arrange the available layers.

4.5.1 Edits and updating of data in GeoExplorer

Two options enabled in GeoExplorer are to create new features and editing existing features. These two tools allow authenticated users to edit or modify the data by adding new attributes and can also change the geometry of existing features. The changes are automatically saved in PostgreSQL/PstGIS database through GeoServer using the SQL protocol, and from the web client applications to the web map server through the HTTP Protocols.

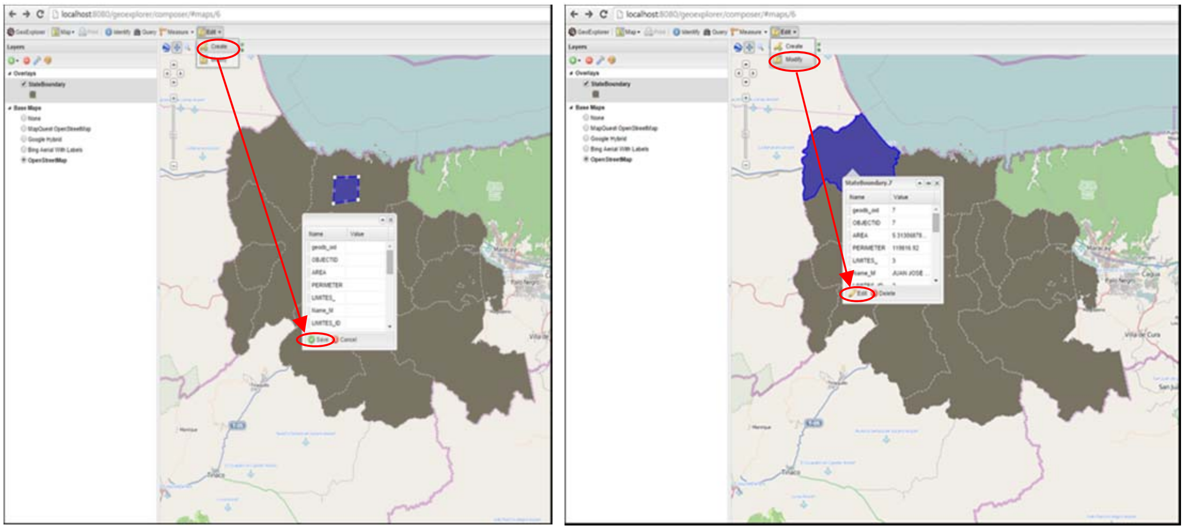

Figure12: Editting and updating of data on Existing layer

4.5.2 Performing Queries in GeoExplorer

In GeoExplorer, the Query tool provides options for querying features in the selected layers. It is possible that features in the selected layers are queried with help of attributes or current map extent. The *query that is performed by current map extent* controls the query operation to present only those features which lie in the current map extent. The Query, which is performed by attributes, provides a query builder to set up a condition of the query. There is also a possibility of performing complex queries by setting up the conditions. When all the necessary conditions are configured, execute the query which will display the output in the form of a table according to given conditions.

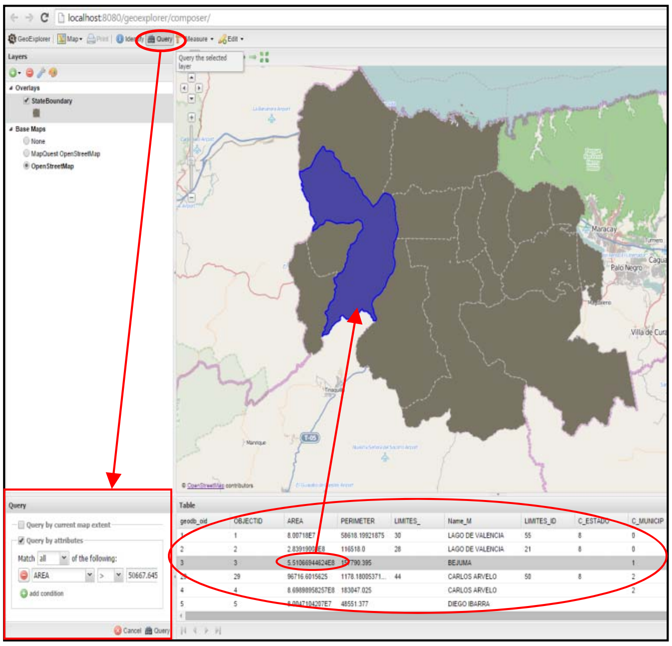

Figure 13: Display the output table of query performed by attribute

4.5.3 Upload External Layers in GeoExplorer

GeoExploere also provide opportunity to the clients to upload external data into GeoExlorer and visualize it. It support archive file (zip, tar, gzip, or bzip) and Geo TIFF file format directly into local instance of GeoServer. The data is then saved automatically into GeoServer in the specific workspace and store. However, it does not support *.shp* format of the shapefiles because upload data process requires a single file but a shapefile includes a number of files like .shp, .shz, and .dbf etc. files. To upload a shapefile, it is necessary to compress the shapefile first into archive and then upload it.

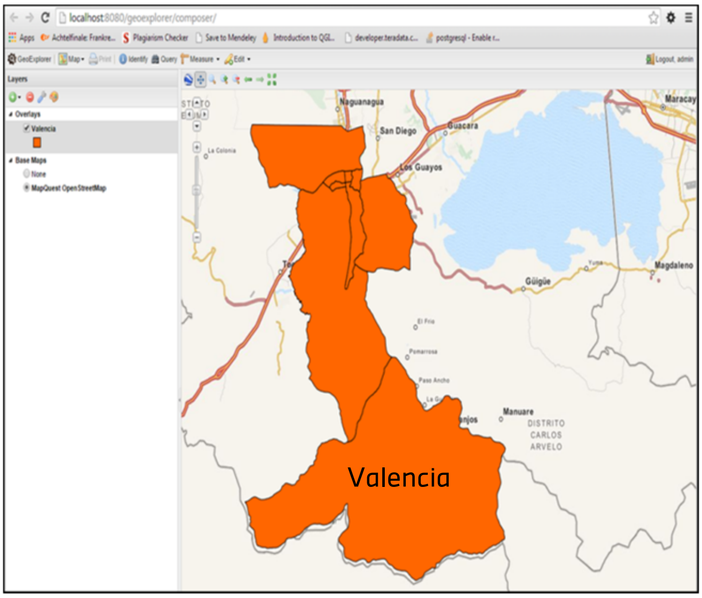

Figure 14: Uploading data externally in GeoExplorer

Figure 14 is showing the required parameters for the uploading of a shapefile externally as well as the visualization of the uploaded layer. The clients has to fil out the required parameters like defining a unique title to the layer, description of the layer, specify the path of the folder from where the data has to be upload and optionally identify the name of the workspcae and store in GeoServer where the data will be save and also assign the co-ordinate to the layer as well.

5 Conclusions

The target of this work – i.e. the modeling of a geodatabase and designing of a Web GIS through its web implementation, as a completely open source solution on a single platform – has been achieved. An easy and effective methodology of work has been followed to attain the objectives. It has been seen that as opposed to commercial web mapping applications, open source GIS technologies have proven to facilitate sharing, communication, interoperability, collaboration and integration of geospatial data on the web in a cost-effective manner. The modeling of the geodatabase as well as the design of the Web GIS has also been explained in detail in this report. The European Caribbean Association could benefit from the many advantages of using of an open source Database Management System. Further, the availability of a Web GIS that focuses on the target locations of the association while at the same time being accessible from multiple locations and by multiple users are some of the stark achievements of this work.

The designed application uses Apache Tomcat as a web server to communicate between the web application clients and the GeoServer. This and the use of the GeoExplorer as a web client application to enable the clients to visualize the data through a web browser bring the work up to the desired academic and professional standards. The complete platform allows the clients to access, edit, update, analyze and effect any other required changes in this Web-based Geo-Information System. Additionally, spatial analysis and visualization on varying scales of the data are also possible.

Accessing of the WMS and WFS services is another challenge in regard with this work that has been done with the help of both open source software (QGIS) and commercial software (ArcGIS). Following this work, these services could be easily accessed using both these software. PostgreSQL is used for database implementation and it is found to have better data access control as compared to the currently used ArcGIS license (ArcMap the lowest version). For the implemented Web GIS, the used OpenGeo Suite platform has both the required components, namely GeoServer and GeoExplorer, as given previously.

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Agent Based Simulation for Suitability of Biogas Power Plants, Case study Schwarzwald-Baar-Kreis, Baden-Württemberg, Germany

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ABSTRACT

Over the past decade, political framework in the energy sector in Germany has provoked a strong focus on the production of renewable energies, particularly through biogas power plants. For this purpose, a sufficient supply of biomass on a regional basis is needed to run biogas plants economically and smoothly. This study focuses on a model-based approach to identify the suitable and economical distribution of biomass power plants over the time in an area of interest, i.e., Schwarzwald-Baar-Kreis Baden-Württemberg, Germany. Based on silage maize suitability and some physical constraints to biogas power plants, the rules for an agent-based model are used to simulate the future installations of power plants. In conjunction with ArcGIS, Agent Analyst software generates simulation results that prove the robustness of the model in finding the suitable location of proposed biogas power plants. This model yields the locations of 30 biogas power plants on the basis of a defined criteria in the Schwarzwald-Baar-Kreis county. The resultant location from the agent-based model is analyzed from different aspects such as analysis with respect to distance to heat consumers as well as available substrate and a statistical analysis for each municipality. It is concluded that the agent analyst results are highly significant for the decision making process.

KEY WORDS: Biogas power plants, silage maize, agent-based model, agent analyst

1 Introduction

Global energy trends, the prospect of irreversible climate change and the demand for energy security highlight the need for a rapid shift to an energy system that is low-carbon, sustainable, efficient and environment friendly. Renewable energies play an important role in the provision of energy services, sustainable mannered and in particular for climate protection [1].

Since the Fukushima nuclear plant disaster in Japan, the German government had provoked a strong focus on the production of renewable energies, amongst others through biogas power plants [2]. Thus, due to the subsidies paid by the government, many agricultural farmers have turned to energy farmers.

As an example, bioenergy production in the Schwarzwald-Baar-Kreis, a county in the state of Baden-Württemberg in the South-West of Germany, has grown in the past decade rapidly. Between 2003 and 2013, there has been a five-fold increase in the installed energy capacity from Biogas Power Plants [3]. Consequently, this has also led to the increase in the number of biogas power plants from 23 in 2002 to 71 as at 2012 [4].

Biogas power plants require a certain combination of substrate composition to produce electricity and heat. Some of the used substrates that make up the total dry matter needed for energy generation are: manure, solid waste, silage maize, whole plant silage, grass silage and others, where the use of silage maize and grain is restricted to 60%. Due to the political and economic framework, it is expected that the number of biogas power plants will continue to increase in the future [5].

To help the discussion in a civic society about the pros and cons of a future development, this study focuses on an agent-based approach to identify the suitable and economical prospective distribution of biomass power plants over the study area.

Agent-based models contain multiple interacting agents situated within a simulation environment. Relationships between interacting agents are specified, linking agents to other agents or other objects within a system. These relations may be specified in different ways, from simply reactive (i.e. agents only perform actions in suitable conditions), to goal-directed (i.e. seeking a particular goal) [6].

Agent-based models (ABMs) can play important roles in biogas power plant location suitability modeling, and answer interesting research questions. For example, ABMs can assist in selecting the appropriate location of biogas power plants based on suitability conditions.

This paper shows how to effectively integrate a spatial ABM of biogas power plants with a GIS for a specific study area (Schwarzwald-Baar-Kreis Baden-Württemberg, Germany). We identify the relevant data layers, and explain how to collect, analyze, and prepare the data for the ABM.

We rank different physical constraints based on their effect on biogas production and energy distribution. Then assign a relative weight to each factor by using the weighted overlay tool in ArcGIS, and build a suitability raster to biogas power plants. Once the data is prepared then link it to the Agent Analyst extension and define additional suitability criteria for point vector as new biogas power plants. These vector points move as agents to a suitable location according to the defined restrictions and relations.

The goal of this project is to implement an interface between the Agent Analyst extension and ArcGIS Desktop for suitability analysis of biomass power plant installations.

1.1 Agent Analyst

The Agent Analyst toolkit was developed by Argonne National Laboratory's Center for Complex Adaptive Agent Systems Simulation Decision and Information Science Division in collaboration with ESRI [8]. The interface between Agent Analyst and ArcGIS allows GIS analysts and experts to model behaviors and processes. With Agent Analyst's graphical user interface (GUI) and ability to run in parallel with ArcGIS, users can create agents, schedule simulations, edit datasets and, most importantly, specify the behavior and interactions of agents.

An environment, also known conceptually as the system, can be composed of three different models: GIS, network, or grid. A GIS model is used for this project to establish a link to ArcGIS Desktop. Within a model, there can be many agents, either vector or generic. The agents act as the components of the agent-based model. Vector agents differentiate themselves from the generic by the ability to inherit attributes from a linked shapefile [7].

2. Literature Review

Several studies have been undertaken related to agent based models and GIS based suitability analysis. In studies relating to agent based simulations, there is a lot of emphasis on dynamic models in space and time domain. This study, however, uses the concept of agent based techniques in relation to future installation of biogas power plants.

Jinzhuo Wu (2011) presented a two-stage approach to select woody biomass-based ethanol plants using GIS in the central Appalachia hardwood region of West Virginia, USA. His idea is borne out of the need to identify suitable locations where the existing industry or power generating facilities is an efficient method to lower energy expenses. He uses the ArcGIS spatial analyst extension to calculate distance from the different physical constraints and computed site suitability index for the study area using a linear fuzzy logic prediction model [8].

Identifying bio-energy potential is very important for any kind of simulation to be done. Similar to the case study in Virginia, Höhn et al. [9] identify suitable sites for biogas plants in southern Finland. With the help of GIS, they calculate kernel density maps to locate areas with highly concentrated biomass. They set specific transportation radius from the biomass source and compare them with the resulting energy the biogas plants are generating.

Collier et al (2013) adds intelligence to randomly moving point agents. In this scenario the point agent have to choose a direction of movement where they can find a higher chance of getting food. With the help of different inputs defining a suitable raster, agents are moving over the raster looking for food. In this way they introduce how to instruct the point agents and move to areas where they remain safe [10].

Sean P. Murphy [11] made a web enabled decision support system for the land managers. In this study, he used Agent Analyst software in conjunction with ArcGIS to simulate future extent of annual brome in the great basin area of Nevada, United States. Based on vegetation classifications and dispersion characteristics, the rules for an agent-based model had been used to simulate the future extents.

3. Study area and methodology

3.1 Study Area

For this study, a county (Landkreis) in the state of Baden-Württemberg in South –West of Germany, known locally as Schwarzwald-Baar-Kreis, is chosen as the study area (see Figure 1).

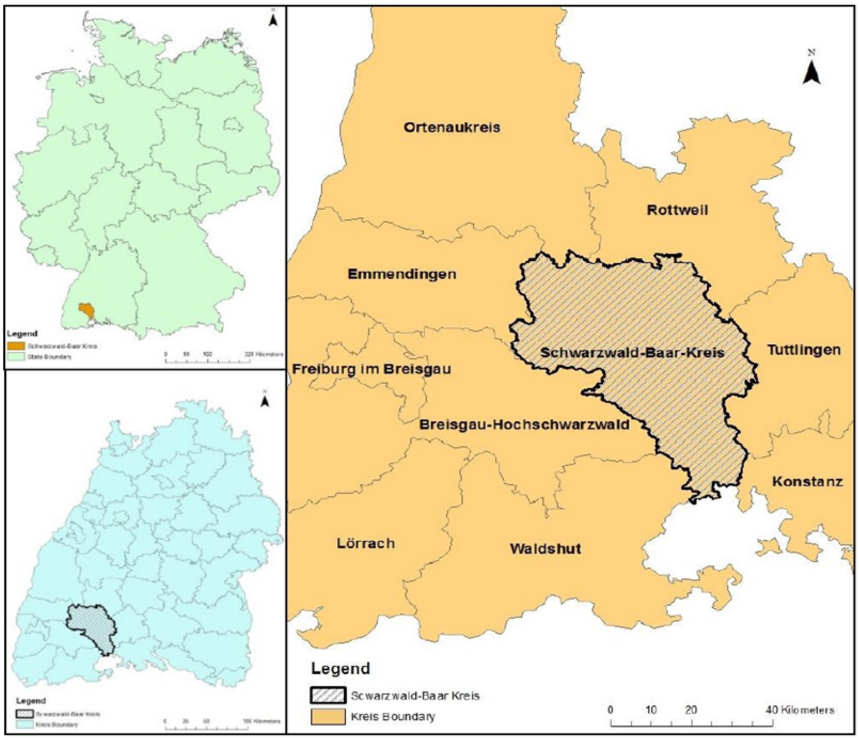

Figure 1: Study area situated in South West Germany

It consists of 20 municipalities (Gemeinden) with Villingen-Schwennigen as the main city. According to the 2012 figures from the Statistischen Landesamt Baden-Württemberg, Schwarzwald-Baar-Kreis has a total area of 102,526 hectares with 204,585 inhabitants and a population density of 200 inhabitants per square kilometer. The county is part of the rural area; about 87% of the county area is forest or agricultural land. The forest areas are concentrated in the northwestern part of the county, where the elevation rises up to 1100m, where most of the cropland can be found in the southeast part with elevations between 470 to 800m.

The average annual rainfall shows a similar pattern: It varies from 1800 mm per year in the North West to less than 600 mm in the southeastern part. The land ownership on the agricultural land shows a small scale structure, the average size of a farm is about 37 ha. According to 2013 statistics from the Statistisches Landesamt Baden-Württemberg, the total number of farms in Schwarzwald-Baar-Kreis is 1037, which include 249 silage maize farms. The cultivation of silage maize increased in the last decade from 721 ha to 2629 ha (2013), corresponding to an increase from 4% to more than 16% of the total cropland in the county. The primary reason for selecting Schwarzwald-Baar-Kreis as study area is the available potential for silage maize that is usable as Biofuel for biogas power plants [5].

According to the International Solar Energy Society there are 71 Biogas Power Plants in operation by the end of 2012 under the Promotion of Renewable Energy Act (Erneuerbare-Energien-Gesetz, EEG). These Power Plants have an installed capacity of about 14 megawatts of electricity.

3.2 Methodology

The GIS-ABM workflow is shown in Fig. 2. The GIS module, (here ArcGIS Desktop 10 is used), produces, processes, and analyzes the different data layers.

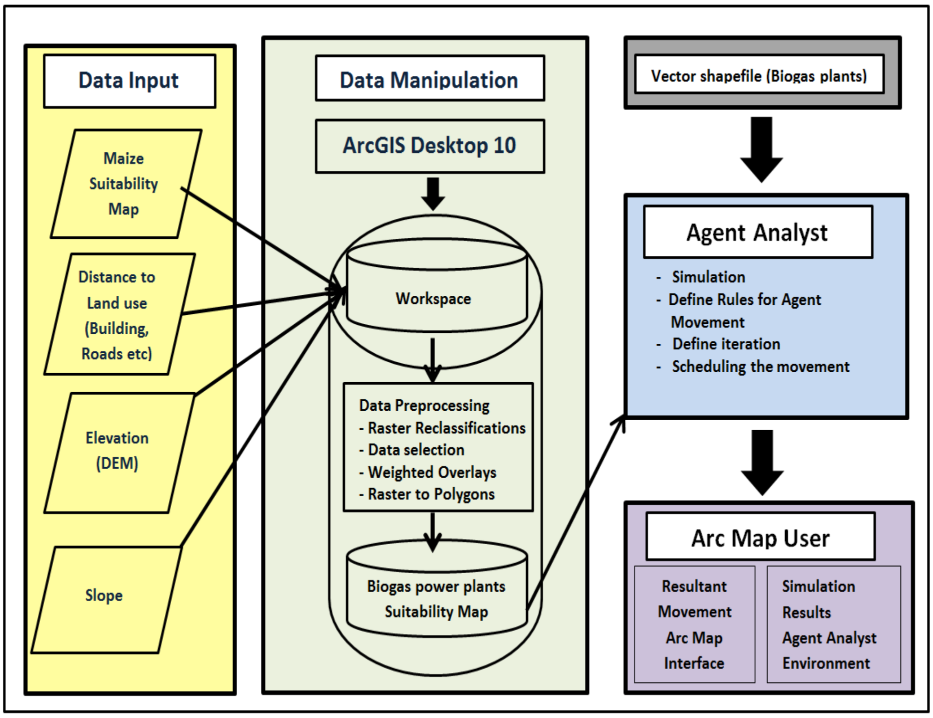

Figure 2: GIS-ABM Workflow

The ArcGIS ModelBuilder is used to prepare the maps which are fed to the Agent Analyst. In ModelBuilder the first phase involves producing a silage maize suitability map following the methodology used by [5].

In the second phase suitable sites for future installation of biogas power plants are identified by using weighted overlay analysis. The vector shape file of existing biogas power plants and random point's shapefile as future biogas power plants are linked as a vector agent in the Agent Analyst environment. These maps and shape files are connected to the Agent Analyst Environment where define criteria for simulation. After completing the simulations in Agent Analyst, the outputs are analyzed using ArcMap.

3.2.1 Data preparation

The available data represent several thematic layers relevant to the study area. To build up a realistic representation of the study area a variety of layers were used. These layers fall into two categories: Silage maize suitability map and biogas power plants suitability criteria. For the Agent Analyst simulation vector shape files of existing and random points as future biogas power plants were created. With the combination of the suitability map for power plants and the vector shape files simulation criteria were defined.

3.2.2 Processing data layers with ArcGIS

To identify suitable areas for silage maize cultivation, a criteria set with four data input. According to Fiorese and Guariso (2009), some of the factors unsuitable for the growth of energy crops are: high slope (greater than 20%); soil pH lower than 5.0 or higher than 8.5; altitude above 750 m; soil containing rocks, gravels or pebbles [13].

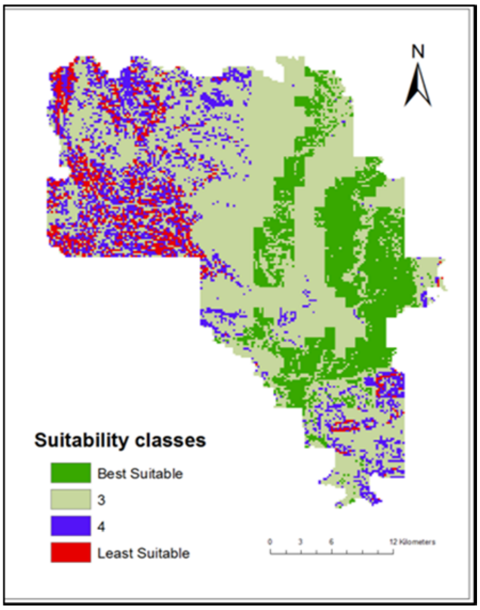

Figure 3: Silage maize suitability map

The maize suitability map is generated by overlaying four input data sets, i.e. slope, soil pH, elevation and stone volume.

This map is divided into four suitability classes, namely; classes 2, 3, 4 and 5. It identifies areas with best suitability as class 2 and those with the least suitability as class 5 Fig. 3.

A piece of land may be suitable to grow silage maize, but may not be available based on the specific land use type such as settlements, restriction zones, and reserves, etc. As a result silage maize suitability areas that fall under such land use types are removed.

Considering the actual state regulation, which ban the conversion of pastures to cropland, agricultural areas dedicated to pasture are not included in the analysis as well. From the data source of CORINE European land Cover, the arable land data extracted and intersected with the suitable maize map of Schwarzwald-Baar-Kreis.

With the described workflow, the silage maize suitability and availability map is derived which is shown in Fig. 4. The total area of first two suitable classes under arable land is about 1300 hectares which is about 83% of the available agricultural area. The suitability map shows that the study area has a great potential for silage maize cultivation.

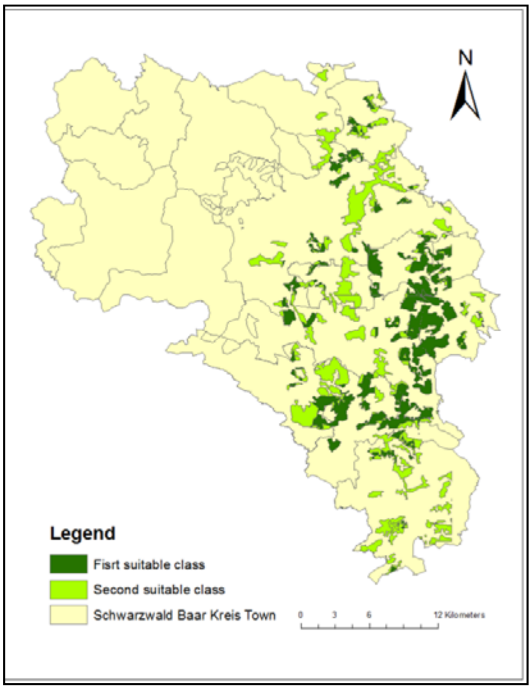

Figure 4: Suitable silage maize area in arable region

To identify the suitable areas for installing new biogas facilities several conflicting and contradicting interests exist between economic, environmental, and social criteria that are the part of the decision-making process of site selection. The most common procedure for multi-criteria evaluation is the Weighted overlay analysis to solve problems such as site selection and suitability models.

According to Jinzhuo Wu (2011) and Epp et al. (2008) different factors can affect the efficiency of power plants, including physical, economic and environmental factors (Table 1) [9].

The distance from community, swimming pool location and road layers were added to model builder and input into the Euclidean Distance tool. This tool calculates distances to particular features as a raster dataset. After reclassifying, the input factors slope, elevation, distance to community, road, swimming pool, and silage maize suitable area map, assign a relative weight and combined into a single dataset as a suitable map for biogas power plants (Table 1).

The final dataset indicates the probabilities of biogas power plants ranging from 1 to 5 at an interval of 1 see Fig. 5. It identifies areas with most suitability as class 1 and those with the least suitability as class 5.

Factors	Attribute	Suitable range	Percentage Influence
Physical condition	Topography	Flat to slightly rolling	
	Elevation	100-700 m	10%
	Slope	0-10 percent	15%
Economic factors	Distance to community	10-1000 m	20%
	Distance to water bodies	100-1000 m	10%
	Distance to road	10-3000 m	5%
	Distance to substrate	1 - 15000 m	40%
Environmental Impacts	Flood plain	Avoid	
	Public land	Outside	
	Wetland	Outside	

Table 5: Site suitability factors biogas power plants

3.2.3 Assumption for simulation

According to Statistisches Landesamt Baden-Württemberg, the total available agricultural area in Schwarzwald-Baar-Kreis is about 15,862 hectares as stated in 2010. The statistics from the silage maize potential area maps show that the first two suitable classes have an area of about 13,000 hectares. However, not all the silage maize produced in the study area is used as feedstock for the biogas power plants. A portion of the silage maize is also used as cattle feed [12].

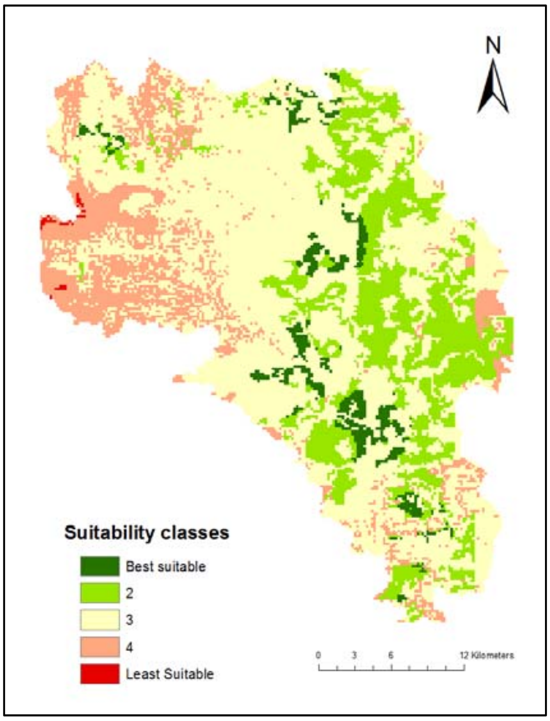

Figure 5: Suitability map for biogas power plants

With the assumption that in the next 10 years in the study area silage maize cultivated area will increase from 16% to 26% of the total agricultural area, then total silage maize contribution increase from 2,629 ha to 4,129 ha maize in the future. Considering the number of cattle in the study area remains same as in 2010, the maize cultivated from the extra 1,500 ha could be used to feed biogas power plants.

Biogas power plants require a certain combination of substrate composition to produce electricity and heat. This composition depends upon the capacity of the plant, small scale power plants use substrates that make up the total dry matter needed for energy generation are: silage maize - 43%, slurry -29%, solid manure - 5%, whole plant silage - 5%, grass silage - 12% and others - 4% [5].

3.2.4 Define criteria for simulation

In this project, future installation of biogas power plants has the main focus, therefore only two data sets are considered, i.e. a point shape file as agents and a silage maize suitable raster. To run simulations with the selected data layers, they are linked to Agent Analyst.

It is essential to determine how much silage maize hectare is needed as feedstock for biogas power plants for producing 1 kilowatt of energy. Dederer (2010) states that approximately 0.5 ha of silage maize is needed to run a power plant with a capacity 1 kilowatts (KW) [14]. As the share of silage maize is about 40 % to the total input material so the 0.2 ha of silage maize is actually used as substrate for 1 kW capacity power plant while the remaining 60 % is used as materials like manure, sugar beet, grass etc. Therefore, in order to determine the number of future installations in the study area by considering the 1,500 ha of new maize cultivated land, it is concluded that by using 40% share of silage maize about 30 biogas power plants have to be added with an average capacity of 250 KW in the next 10 years.

The GIS data layer that contains the points for future installation, is first created randomly according to density of suitable area for power plants Fig. 6. While running the simulation from Agent Analyst these points locate these points at suitable locations, proper criteria/set of rules in Agent Analyst environment are defined so that these points move to their best suitable location.

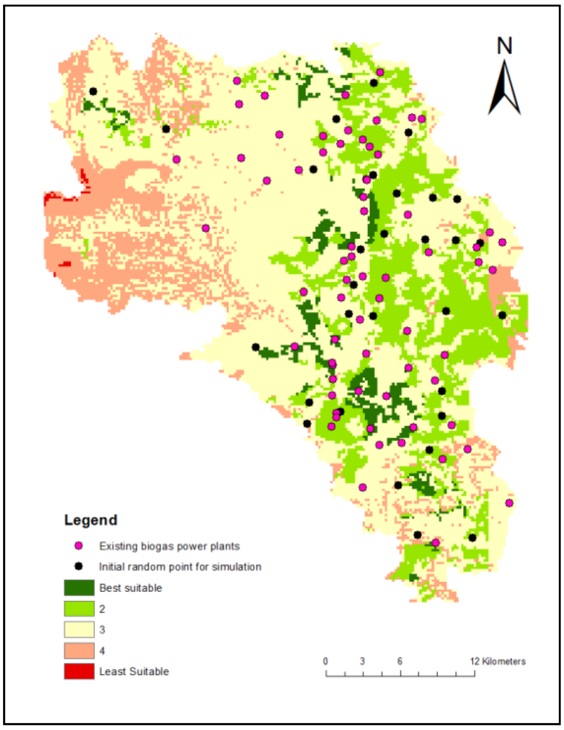

Figure 6: Existing power plants and random point for simulation

Initially in the Agent Analyst environment, the movement of these 30 randomly distributed points was set to move in random directions to seek for their best suitable pixel.

These randomly moving points alter their direction if they are in the vicinity of the existing points or others among themselves. The buffer area is defined around the new points and also around the existing power plants so as to settle the new power plants at a certain distance from the others. If the point moves outside the study area boundary then it changes its direction at an angle of 180 degrees to the direction of movement.

The moving point stops its movement when it finds suitable cells over the suitable raster of biogas power plants. If this point finds the suitable cells then this point has to check at least 8 surrounding cells with same raster values, so that this point has enough space for the substrate and for construction.

According to the area ratio of two suitable classes of the suitable biogas power plant raster generated from weighted overlay analysis, a certain number of biogas power plants (points) can be accomodated in each class. In this case, it is observed from the suitable raster that the class 1 is smaller in area as compared to class 2. Due to this, 5 biogas power plants were assigned to class 1 and 25 for the class 2.

After the simulation run, the random point moved to their suitable position according to suitable raster values and defined criteria. The final map for future installations of biogas power plants as shown in Fig. 7.

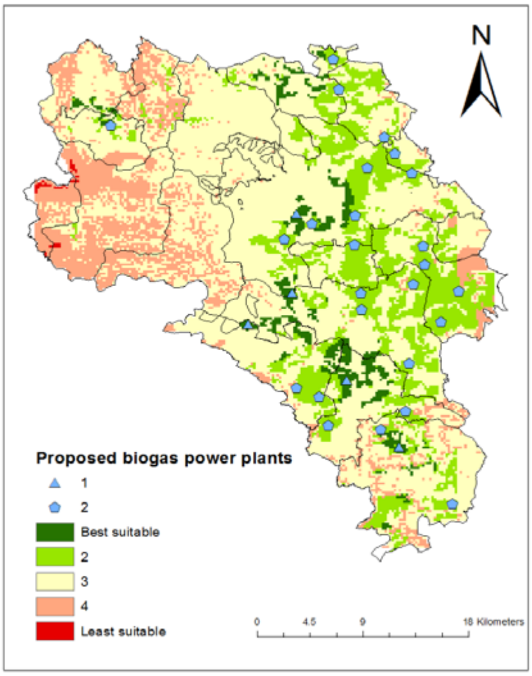

Figure 7: Simulation Result

The movement of the assigned number of agents was random during the simulation. With the random behavior, points adjust themselves according to the assigned criteria over suitable raster. Because of its random nature, the points adjust themselves at different locations at the end of every simulation. However, in every simulation, points are located at a suitable place, according to defined rules over the biogas power plants suitable raster. To analyze the pattern of the settled points in the result of five simulations, a density map was generated as shown in Fig 8.

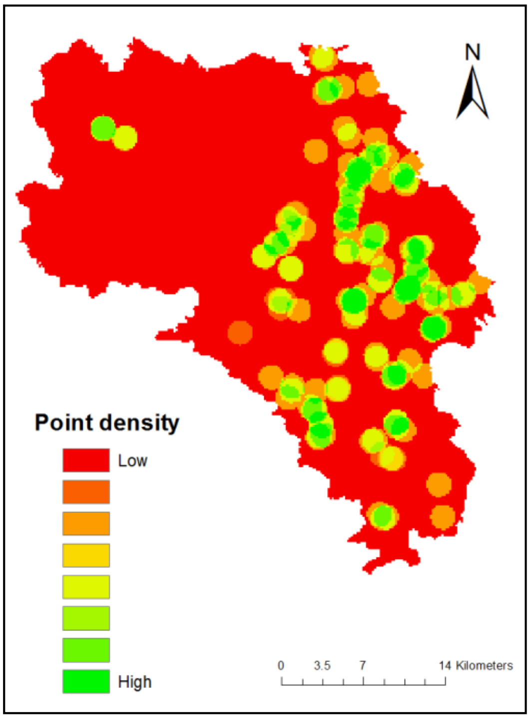

Figure 8: Density map

4. Analysis and conclusions

4.1 Analysis

The location for biogas power plants have been derived with defined criteria. From the two most suitable classes the most suitable class has about 15% of the area of the second one. By considering this area ratio in both classes, we define a quota for biogas power plants, 5 and 25 respectively during the simulation - run. Fig.7 shows the distribution of power plants that could plant in future.

4.1.1 Buffer Analysis for future and existing installations

In previous chapter, the energy-hectare ratio has been established which is used to derive the buffer distance, that represents the silage maize area that is required for each biogas power plant.

The average power capacity of each new biogas power plant is considered as 250 KW. Based on this consideration, each biogas power plant requires a coverage area of 50 hectares of silage maize. In order to create a coverage area of 50 ha, an approximate buffer distance of about 400 meters (m) is required.

To analyze the running situation, buffer analysis shows the points that overlap each other, affecting the efficiency of biogas power plants due to the insufficient substrate as shown in Fig. 9

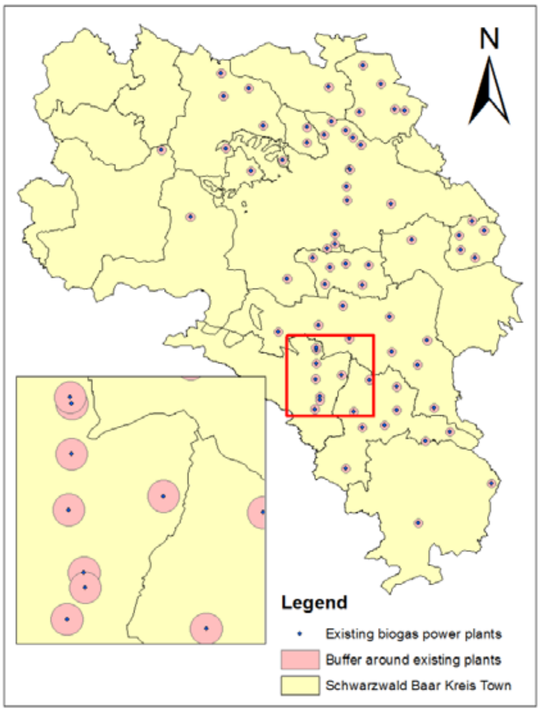

Figure 9: Buffer around existing power plants

According to statistical information of ' International Solar Energy Society ', the average capacity of existing biogas power plants is about 250 kilowatts power. These power plants need at least 40 % silage maize and 60% other substrate to run smoothly.

The present analysis of overlapping area is made for all existing power plants as a whole. However, as the power plants have different power capability and different ownership, in practice the biomass needs calculation must be made individually. Ideally, each biogas power plant should have a fixed coverage area of maize-crop without overlapping areas. The locations of the future biogas power plants are derived with defined criteria through Agent Analyst, such that there is no overlapping area either with existing plants nor with the new plants as shown in Fig. 10.

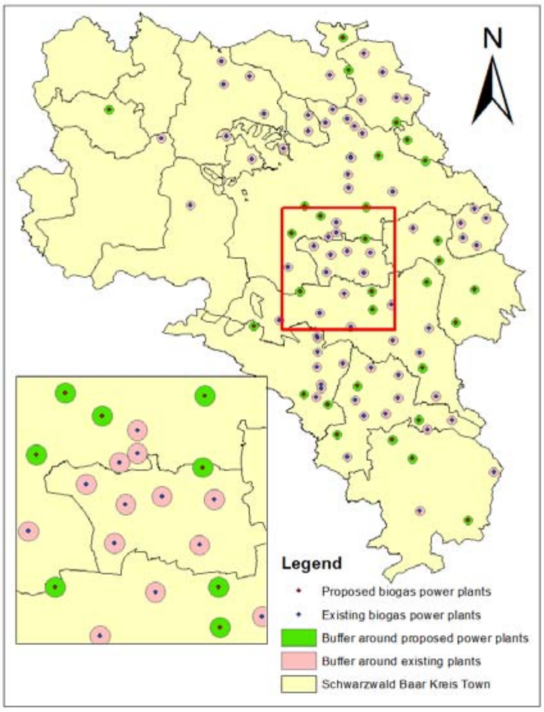

Figure 10: Overlapping buffer area for existing plants

4.1.2 Near Distance Analysis

The locations of power plants depend on a variety of factors such as the availability of substrate (silage maize, grass, manure), possibilities to use the produced energy (Communities, industries, hospitals, school), production costs and transportation costs.

Combined Heat and Power (CHP) generates two types of energy: electricity and heat. For the efficient use of produced heat, biogas plants should be located where suitable demands for heat consumption exist. Most of the proposed locations for biogas power plants in the study area lie near the community within a suitable distance range that is about 10 m – 1000 m as shown in Fig. 11.

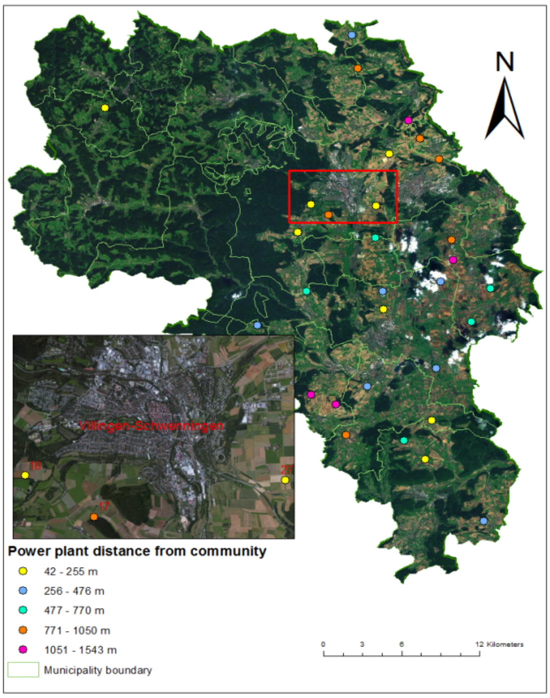

Figure 11: Map of distance from community

A significant number of points lie around Villingen-Schwingen municipality because this municipality has a large coverage area with a large residential area as compared to other municipalities. Similarly the swimming pools are also heat consumers that can buy the produced heat from biogas power plant to warm water. In Fig. 12 shows some proposed location near the swimming pools so that these plants can sell heat to these swimming pools in the future to increase profit.

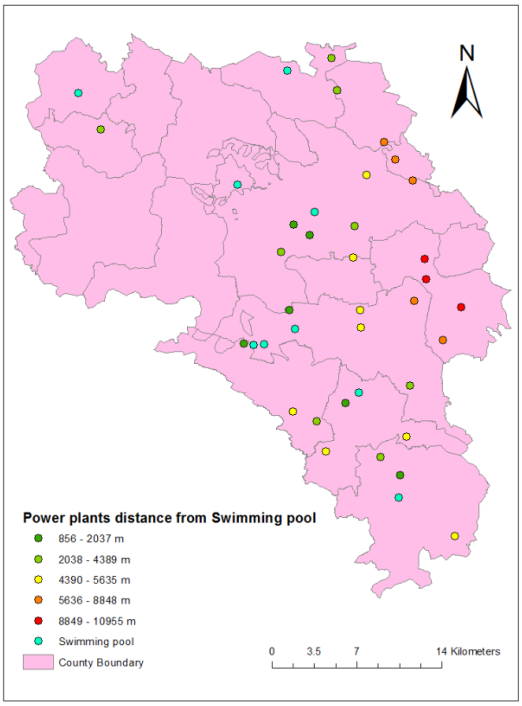

Figure 12: Map of distance from swimming pool

4.1.3 Statistical Analysis

To analyze the future scenario, statistical analysis is carried out in Schwarzwald county at the level of municipalities. There are 20 municipalities in the study area among which villingen-schwingen and Donaueschingen are bigger as compared to others. Some of the counties lie within a region that is suitable for growth of silage maize. Fig. 13 shows the total area and possible silage maize suitable area in hectares within each municipality. The given graph shows that some of the municipalities have potential for cultivation of silage maize that can be used as feedstock for biogas power plants in the future. The municipalities Villingen-Schwenningen, Donaueschingen, Hüfingen, Bad Dürrheim and Blumberg show the high potential of silage maize cultivation as compared to others.

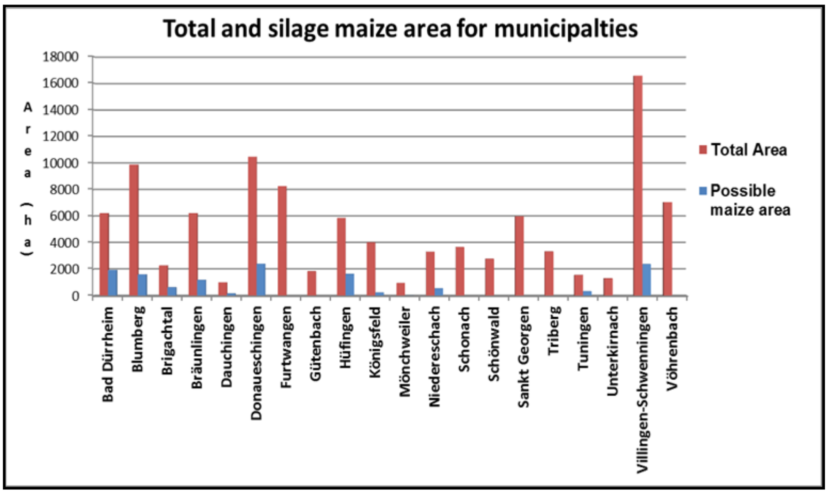

Figure 13: Possible silage maize in Schwarzwald-Baar-Kreis counties

By considering the energy hectare ratio and possible increase in silage maize area, the graph in Fig. 14 shows the proposed and existing biogas power plants in each county. The Villingen-Schwenningen and Donaueschingen municipalities have the potential of silage maize of about 2400 hectares. Also the demand of energy is higher in these areas because of a large number of residences in these municipalities. These areas have a higher number of biogas power plants as compared to other municipalities.

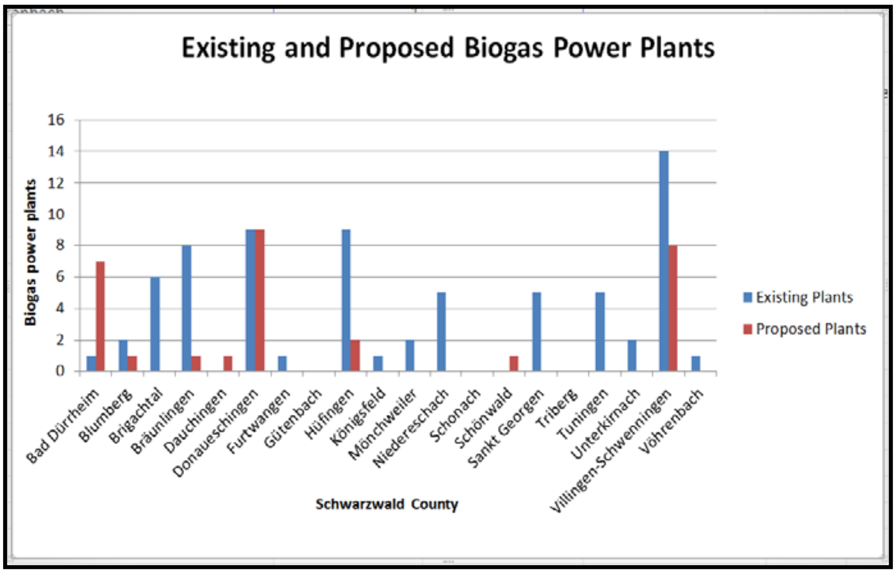

Figure 14: Biogas power plants in Schwarzwald-Baar-Kreis counties

<table>
<tr><th>Nr.</th><th>Parameter</th><th colspan="2">Existing</th><th>Proposed</th><th>Total</th></tr>
<tr><td>1</td><td>Number of Biogas power plants</td><td colspan="2">71</td><td>30</td><td>101</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Silage maize</td><td colspan="2">2629 hectares</td><td rowspan="2">1,500 ha</td><td rowspan="2">4,129 ha</td></tr>
<tr><td>2000 ha Biogas</td><td>629 ha Animal</td></tr>
<tr><td>3</td><td>Power plants capacity</td><td colspan="2">14 MW</td><td>7.5 MW</td><td>21.5 MW</td></tr>
<tr><td>4</td><td>Energy (MWh/year)</td><td colspan="2">112</td><td>60</td><td>172</td></tr>
</table>

Table 6: Analysis of power plants

An increase in biogas power plants requires additional silage maize to feed. With this increase, the overall capacity of power generation in Schwarzwald-Baar will be moved up. A comparison between present and future scenario is shown in the Table 2.

4.2 Conclusions

Agricultural biogas has the potential to increase its contribution in the production of energy over the next few years. In this context, an agent-based methodology was developed that estimates the location of biogas power plants in Schwarzwals-Baar-Kreis. The model is also applicable to any other suitability analysis but may need some modification to change data sets and criteria in the Agent Analyst. These simulation results are highly significant at regional level and indicate a valuable decision support system for land managers in conjunction of ArcGIS and Agent Analyst software.

The simulation outcome has proven to be robust in finding the location of the biogas power plants automatically where they can run economically and smoothly. All the 30 biogas plants, introduced according to the available feedstock, are within a maximum transportation radius of 15 km. Another salient feature of the results is that most of the biogas power plants' locations are set to be close to the residential area due to the high availability of preferential biomass resources (e.g. Biowaste) and energy demand allocation, thus decreasing the transportation distances and transportation costs.

4.3 Limitations

In producing the biogas power plants suitability map, not all suitability factors are considered, i.e. grid station distances, transportation cost, etc. Some estimation is made, where there is a restriction due to the unavailability of statistical data. Agent/based models are formed consisting of high level of autonomy such that the pedestrians are simulated based on a set of rules. Models so made are complex, making their analysis hard and requiring a high level of computational power. Due to the recent release of the Agent Analyst, there are a very limited number of available debugging tools. Any modeller needs to be familiar with the specific syntax of Python and any of the used Java classes. The issues with programming models and development time along with realistic effect of agent movement and activity spaces could be decrease provided the above problems are solved.

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Recommendations for a Regional Spatial Data Infrastructure to Mobilize Knowledge for Mountain Area Development in Hindu Kush Himalaya Region

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KEYWORDS: Spatial Data Infrastructure, INSPIRE, CityGML, ICIMOD

ABSTRACT:

In recent years, the advent of Spatial Data Infrastructures (SDIs), and the distributed and network services based on these data infrastructures have helped to rapidly solve real problems of human being. Apart from addressing the real problems, it also deals with the challenges of interoperability, standardization of services and data acquisition and sharing among and within national, regional, and international bodies. The International Centre for Integrated Mountain Development (ICIMOD) is a regional intergovernmental learning and knowledge sharing centre serving the eight regional member countries of the Hindu Kush Himalayas (HKH)– Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan –and based in Kathmandu, Nepal. ICIMOD aims to assist mountain people to understand changes related with the livelihoods of mountain people and the stability of fragile mountain ecosystems cause by climate change and globalization. ICIMOD has promoted the use of GIS and Earth observation applications to support its strategic priorities. Its Mountain Environment and Natural Resources Information System (MENRIS) Division is a regional resource centre for such applications and is promoting a Regional SDI for the HKH region. This initiative towards an integrated regional SDI, is a landmark development for the sustainable development of mountain area communities. In this research work, currently available state of the art SDIs like INSPIRE project of EU and international 3D data modelling standard CityGML are reviewed for their idea and services. The infrastructures initiated under INSPIRE directive have helped in rapid development of applications to confront challenges of communities. We proposed and give recommendations to utilize and integrate the ideas of INSPIRE and CityGML with the proposed regional SDI of HKH to give greater benefits to communities and for sustainable environment vis-a-vis culture of mountain areas.

Micro-UAVs- An alternate Route to Earth Observation for Geospatial Community

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North East Center for Technology Application and Reach., Department of Science & Technology, Government of India

KEYWORDS: Micro-UAV; Geo-information; Geospatial Community; 3D city building; 3D Models; Earth Observation platforms

ABSTRACT:

Geo-Information is the Information about the earth surface features & its natural environment in the form of maps and databases which is necessary in almost all fields of human activities. This may range from planning & construction of a house to building a bridge and use of cell phones to Air space vehicles. The development of Computer Science and Applied Mathematics enable us to use this information as decision support in diverse complex scenarios encountered in Private and Government organizations. There are a numerous ways that we can collect this information, but its quality and quantity always matters a lot to specific Geospatial Applications. Micro-UAVs, a new bird in the sky, could be one of the means to collect accurate Geo-information which is creating a silent revolution for the world Geospatial Community. It is the technology innovation in the field of Computer Science in the form of GPU, Multiple Core processor, Computer Vision algorithms, GNSS, Autopilot, Lightweight high-performance batteries and High Resolution & Low cost sensors enable the aerial system to collect information not only for smaller but also for larger geographical extents. In spite of diverse global issues like safety, security, privacy and insurance etc to regularize the technology in civil applications, almost all the developed & developing countries are collecting & analyzing geo-information through micro-UAVs and implementing in different small scale to medium scale projects effectively. The authors in this paper have attempted to showcase practical applications of this technology in diverse areas. Three different case studies carried out for water resources management, 3D city building & 3D virtual Models for heritage site applications were analyzed in detail. Horizontal & Vertical accuracy, GSD and flexibility of operation with minimum logistics are the key strengths of this technology which are established through this paper. It is observed, from the benefits and potential applications as shown in this paper, that the technology is well ahead and this could be an alternate solution in Earth observation over satellite and manned aerial observation, and therefore, can be justified as an "Alternate Route to earth observation for Geospatial community". It not only delivers a quality product but also provide cost effective solutions when compared to other observation platforms. The only hindrances for its wide applicability could be attributed to the non formulation of coherent and continuous RPAS policy, clarity of international & national layers, regulatory framework, operation issues like safety, security, privacy and insurance all in accordance with R & D results. Apart from this a few challenges yet to be resolved and future trends have also been discussed.

1 Introduction

Geo-Information is the Information about the earth surface features & its natural environment in the form of maps and databases which is necessary in almost all fields of human activities. This may range from planning & construction of a house to building a bridge and use of cell phones to Air Space Vehicles. The development of Computer Science and Applied Mathematics enable us to use this information as decision support in diverse complex scenarios encountered in Private and Government organizations. There are a numerous ways that we can collect this information, but its quality and quantity always matters a lot to specific Geospatial Applications. Micro-UAVs, a new bird in the sky, could be one of the means to collect accurate Geo-information which is creating a silent revolution for the world Geospatial Community. The increasing developments in Unmanned Aerial Vehicles (UAVs) platforms and associated sensing technologies, adapted to these platforms, offer a broad range of solutions for different applications related to the acquisition of information about objects, structures or phenomenon at the Earth level, based on observations on the surface seas and oceans and in the atmosphere. The cost-effectiveness compared to manned vehicles makes them attractive, especially considering that UAVs can be equipped with several onboard sensors, including optical and hyper spectral camera-based, Laser, SAR, IMU, GPS among others.

The huge amount of data, provided by UAVs, represents a new challenge regarding developments of processing, storage and transmission techniques. It is the technology innovation in the field of Computer Science in the form of GPU, Multiple Core processor, Computer Vision algorithms, GNSS, Autopilot, Lightweight high-performance batteries and High Resolution & Low cost sensors enable the aerial system to collect information not only for smaller but also for larger geographical extents.

In spite of diverse global issues like safety, security, privacy and insurance etc to regularize the technology in civil applications, almost all the developed & developing countries are collecting & analysing geo-information through micro-UAVs and implementing in different small scale to medium scale projects effectively.

The authors in this paper have attempted to showcase practical applications of this Technology in diverse areas. Three different case studies carried out for (i) Water Resources Management, (ii) 3D City Building and (iii) 3D virtual Models for heritage site applications were analysed in detail. Horizontal & Vertical accuracy, GSD and flexibility of operation with minimum logistics are the key strengths of this technology which are established through this paper. It is observed, from the benefits and potential applications as shown in this paper, that the technology is well ahead and this could be an alternate solution in Earth observation over satellite and manned aerial observation, and therefore, can be justified as an "Alternate Route to earth observation for Geospatial community". It not only delivers a quality product but also provide cost effective solutions when compared to other observation platforms. The only hindrances for its wide applicability could be attributed to the non formulation of coherent and continuous RPAS policy, clarity of international & national layers, regulatory framework, operation issues like safety, security, privacy and insurance all in accordance with R & D results. Apart from this a few challenges yet to be resolved and future trends have also been discussed.

2 Technology

2.1 Micro-UAVs developed by NECTAR

There are number of aerial platforms generally used for collection of geo-information meant for different applications. The main concerned parameters considered for aerial collection are spatial resolution, spectral quality owing to visual discrimination of different earth features (Radiometric Quality), Easy and convenient operation of aerial platform/vehicles, cost of operation and safety & security with legal permission to fly over an area of interest. Considering to these above parameters we have seen variety of systems of manned aerial vehicles with different types of sensors, satellites with sensors ranging from low to high definition earth observation etc. Each platform has their own pros & cons in respect to operation and output quality. UAV is one of the other platforms which have impacted its potential in the international mapping or geospatial community replacing many components of geospatial data collection. The North East Centre for Technology Application and Reach (NECTAR) has developed pair of such vehicles specially designed for mapping applications which can cover large extent of area with very good resolution.

- Fixed Wing: The first UAV developed by NECTAR is fixed wing Micro-UAV, a self-guided plane that can carry different types of consumer sensors creates GPS-based (Global Positioning System) digital images. It is a radio controlled model glider plane equipped with a small GPS, a miniature autopilot and consumer grade digital camera. The UAV can be hand launched and automated from take off to landing. The UAV is simple to operate, simply stand at one corner of the field or an area and hand launch the 5 pound plane. The powerful miniature autopilot and GPS, does the rest navigating in a pattern over the field. Both the vehicle and the camera perform automatically in acquiring GPS based digital imagery. After the flight session, UAV lands at the spot where it took off. The UAV mounted with 12 MP Camera can fly at approximately up to 300 meter above the ground and acquire the digital images that could provide a spatial resolution of approximately 8 cm (GSD). However, increased spatial resolution can be achieved by simply programming to fly at much lower altitude or closer to the ground. With its 150 cm length and 190 cm wing span (weight about 3kg) can fly 1.60 sq km in one flight of approximately 40 minutes depending on wind. It also offers real time video with ability to capture images from ground station and also the user can stitch all the digital images to form a single large image. The UAV can take payload up to 250 gm. The detail specs are given below:

Fig. 1 Fixed wing Micro-UAV used for the study

Wingspan	190 cm
Length	150 cm
Wing area	50 dm2
Maximum Takeoff weight	3 kg
Payload	250 g m
Cruise Speed	40 kmph
Endurance	40 Min
Operating Radious	7 km
Launch	Hand
Landing	Belly

Table 1: Specifications of Fixed wing Micro-UAV used for the study

- Rotary Wing: NECTAR has developed the 2nd Micro-UAV, a quad-copter, i.e., a UAV with four rotors, with a diameter of approximately 1 meter. It is a vertical takeoff and landing (VTOL) UAV that can fly by remote control manually or autonomously through a GPS waypoint navigation system. The Maximum flight time is approximately 30 minutes depending of several factors such as payload weight and wind speed. It can carry a maximum of 250g of payload. The detailed specs are given below.

Fig. 1 Multirotor (Quad copter) Micro-UAV used for the study

Length (m)	0.96
Width(m)	0.96
Empty Weight(kg)	2
Payload (kg)	0.3
Max Takeoff weight (kg)	2.6
Endurance (min)	30
Max Speed (km/hr)	40
Typical operative altitude(m)	100-300
Ceiling (km)	1
Propulsion	Electric Motor
Navigation	GPS
Fuel	Lithium Battery
Rate of Vertical climb (m/sec)	5
Horizontal position accuracy when hovering(m)	± 5
Vertical Positional accuracy when hovering(m)	± 2
Launch & Recovery	Autonomous
Takeoff and Landing area(sqm)	4
Remote control Radius(km)	1

Table 2: Specifications of Quad Copter Micro-UAV used for the study

- Imaging Sensors: Since NECTAR has developed different UAV platforms which are capable of carrying different types of sensors depending on the type of project, it has a range of collection of consumer grade sensor Models like SX 260 , S100 from Canon, RICOH WG-4 GPS from RICOH , NXU (5&7) series from Sony and ADC lite Multispectral camera from TETRACAM. Here we have provided specifications of the Canon S100 Model, which was used for the three case studies presented in the paper.

Fig. 3 : Canon S100 Sensor used for study

Focal length	**5.2 ~ 26mm f/2.0 ~ 5.9.**
Sensor size & Resolution	**1/1.7.", 12MP**
weight	**194 gm**
Power & Shutter	**NB-5L Li-Ion battery, 15 Seconds - 1/2,000, will vary by setting.**

Table 3: Specifications of Canon S100 Sensor used for the study

3 Data processing Hardware and software:

The UAV is allowed to collect image data with 80% overlap and 40 % side lap which produce large number of Image data (around 20,000 numbers of images pertaining to area of 60 sq km). Processing this large number of images requires a lot of computation power and time. It would be a herculean task if processing is done through an ordinary workstation, therefore high end GPU enabled workstation needs to be used which should have at least 12 numbers of cores of processor and high end graphics card. Also the software has to be selected in such a way that it can use the power of hardware resources along with algorithms based on computer vision technology/ digital photogrammetric matching technology.

3.1 GPU enabled High End Workstation Specs

Key components	Specs
Graphic Processing Unit	NVIDIA Quadro K5000 4GB Graphics Card
Operating System	Windows 7 Pro 64 Bit
Multi Core Processor	Intel Xeon E5-2697 v2 2.70Ghz 30MB 1866 12Core Dual CPU (Total 24 Cores)
RAM	64GB DDR3-1866 (4x16GB) CPU Registered RAM

Table 4: Specifications of High End workstation used for processing.

3.2 AgiSoft Photoscan Professional software:

Agisoft PhotoScan is a stand-alone software product developed by Agisoft LLC

St.Petersburg, Russia, that performs photogrammetric processing of digital images and generates 3D spatial data. It has capability to perform verity of tasks in the field of geospatial image data processing. It performs jobs like Photogrammetric triangulation, generation of dense point cloud with editing and classification, export out Digital Elevation Model & Digital Surface Model & Orthomosaics and also allows us to customize processing workflows using Python scripts.

3.3 Skyline Tearrabuilder (City Builder and PhotoMesh) software:

The TerraBuilder family of software products, developed by Skyline Software Systems, Inc., is a US based company, leading provider of 3D earth visualization software and services. It has a number of tools that generates terrain and urban model databases from a wide variety of data types. It allows to merges aerial photos, satellite images, and digital elevation models of different sizes and resolutions into a photo-realistic, geographically accurate terrain database. It has two other tools (i)

CityBuilder which merges 3D mesh models together with classification layers, and/or other model layers into a multi-resolution and stream-optimized 3D Mesh Layer database (3DML). (ii) PhotoMesh, allows to automatic generation of high-resolution, textured, 3D mesh models from a set of oblique 2D images.

4 Case study 1 - Water Resources Applications

4.1 Objective of the study

Tap rain water through small check dams and abandoned open mine pits over an area to develop a sustainable drinking water supply to nearby habitations. Since the objective demands a detailed land use and land cover map along with high definition surface model to create water storage and plan flow using gravity and head loss, technology had to be established to generate such maps /models with relatively less time and economically.

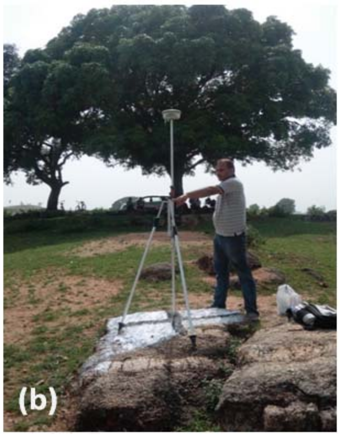
Area of the interest: The area was 15 km North West of Ranchi City in Jharkhand state of India. The total area is 56 sq km.

4.2 Materials & Method used:

UAV System and sensors selected: The area under study was planned for imaging through the fixed wing UAV system which was developed in house and its specifications tabulated in the table 1 above. The Canon S100 Consumer Camera was used for imaging. Apart from the system and sensor, 1 Laptop loaded with Mission Planner software, 1 set of telemetry system with Radio controller, adequate pre charged batteries to replace old batteries, 2 operators one each responsible to control UAV during launching and landing operation (RC operator) & Ground crew station responsible to design the flight line at the study area and monitor UAV attitude, battery status, number of navigation satellite, and data link between UAV and computer at the ground station.

4.3 Differential GPS survey

Prior to imaging the areas were also planned for Ground Control Points (GCPs) and 60 GCPs locations were selected distributing over the area. Three Differential GPS Leica Viva GS12 120 channel GNSS receivers were used with one at master point and two receivers for rover observation for duration of 10-15 minutes. The points were then post processed in Leica Geo Office GPS data Processing software and precise coordinates were computed. The accuracy of observed GPS points was achieved as 14 mm. The complete task was accomplished in 5 working days with 3 operators and 2 assistants. For pre pointing the GCP locations were also highlighted by painting rectangular patch of size 30 cm X 30 cm white marking with black cross in the middle as shown in the Fig 4 (a) and (b) . The Fig 4 (c) depicts the distribution of the all GCP locations surveyed.



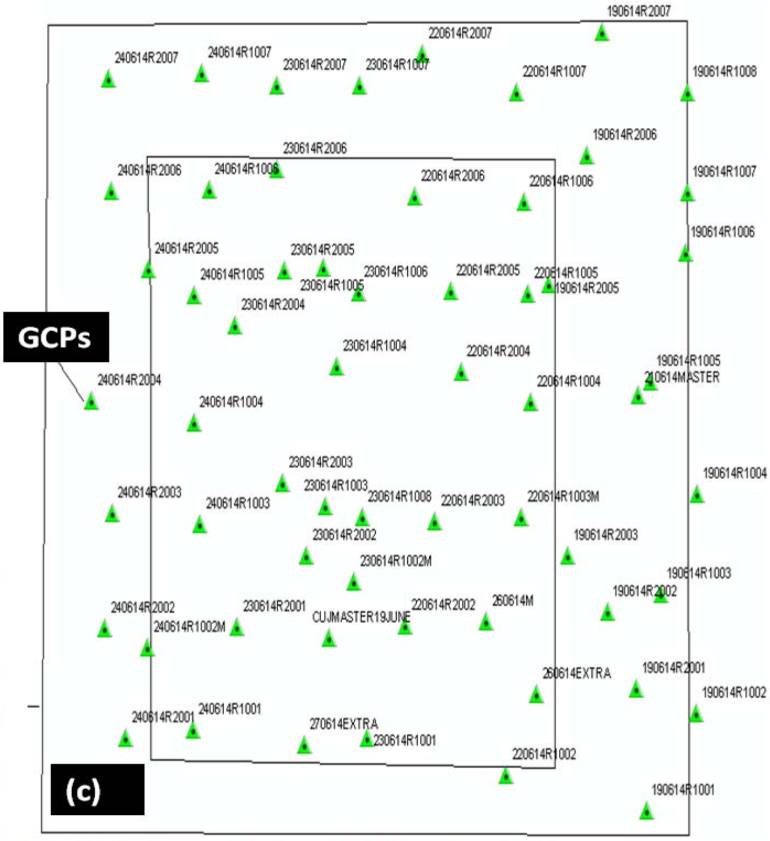


Fig4: (a) Setting up Master DGPS Receiver (b) Observation on a Rover Point Location (c) Distribution of Differential GPS Survey

4.4 Image acquisition

Before flight mission, the team had chosen a suitable location for launching the missions. Then an operator tested all electronic components like speed control, UAV body such as rudder, elevator and main frame, onboard GPS, camera mount, digital camera and propeller. In this study, we had applied autonomous flight mission to fly at an altitude 200-230 meter Above Ground Level. The sensor was programmed to capture images at automatic shooting ground distance of 60 m to achieve 80 % overlap, 40 % end lap with adjustment of the speed of the aerial vehicle over the study area. The images acquired in each mission were checked for its radiometric quality, overlap status, GPS coordinate and gap area. All the checks were conducted on the same evening on the days of flight. The problems were addressed accordingly on the next day on ground with a repeat flight or as was necessary. However, a very few missions were noticed with such shortcomings which necessitated re-flying. Over 20,000 images were captured to cover the whole study area of about 56 sq km. The flight mission took about 49 number of Mission in 7 numbers of days. In total 20 hrs of Flight were accomplished to complete the area.

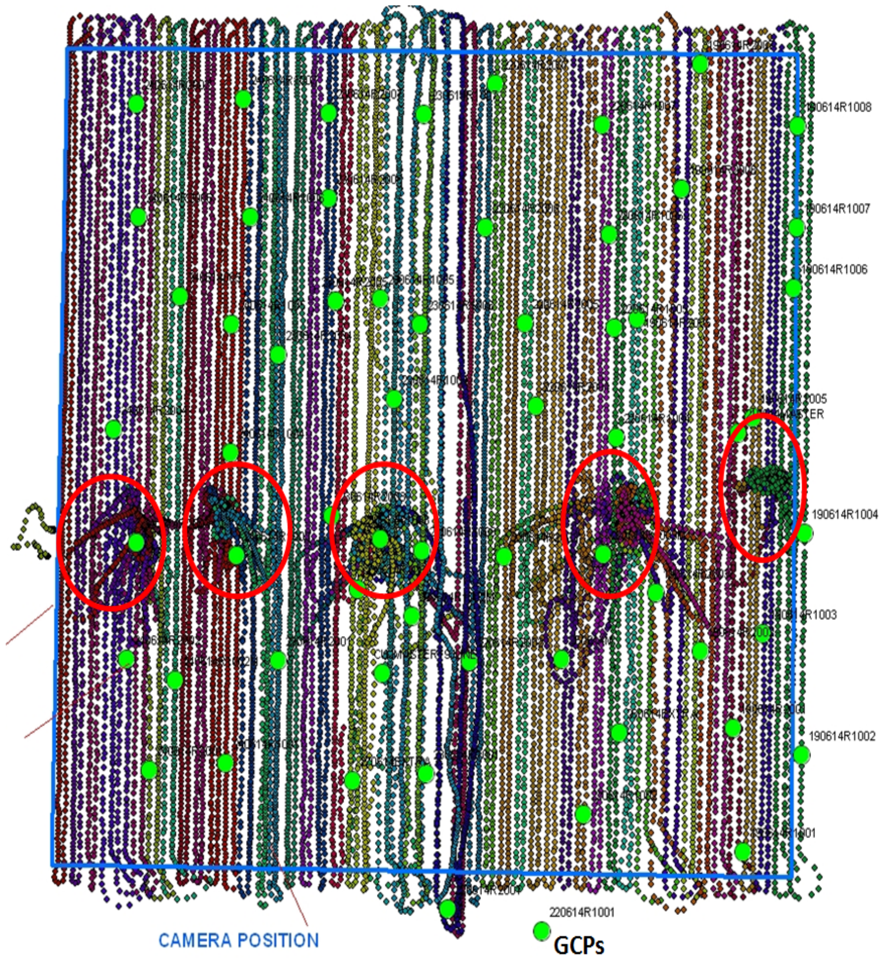


Fig 5: Camera Exposure Geo -Locations after all the Flight Missions completed with encircled launching locations & GCPs Superimposed

4.5 Image Processing

The quality of the images were checked thoroughly again in respect such as blurring image, color balancing and high oblique view during the turning of UAVs at the edge of the Area of interest caused during flight mission. These problems usually arise from the attitude of the UAV during flight. All good quality images were being utilized for the photogrammetric processing. Agisoft Photoscan professional software was used for processing. The software is based on computer vision algorithms which do their very best to estimate the internal parameters of the optical system and the spatial positioning of the image acquisition stations. Using the EXIF data tagged in each of the images were responsible to align all acquired images in the same condition in which these images were taken during flight mission. The parallel processing was done for all 20,000 images distributing equally and overlapping part of images in 03 GPU enabled high end workstations as specified in the beginning of the paper. After alignment using the EXIF data, ground control points were measured by accurate pin pointing with the help of markers (White & black paint markings) visible on images. During Ground Control Point measurement, 5 known GCP locations distributing all over the area were used as Check points for accuracy estimation. In an average, there was 0.44 to 0.52 pixels of error were achieved in photogrammetric triangulation process. After that, dense point cloud generation process followed by dense mesh & texture computation was done to generate a Digital Surface Model and Orthophoto. Fig 6 shows the processing window and dense point cloud generating through Agisoft Professional software. All the products so generated in three workstations, merged into single outputs using ERDAS Imagine software. About 10 cm horizontal and 13 cm vertical accuracy was achieved for 5 check points. The Fig. 7 shows the resultant orthophoto obtained with the accuracy achieved as presented in the tabular format at Fig. 7(e). The Fig. 8 shows snapshots of DSM obtained for a part of the area. Also the utility of these products analyzed for water resources applications as shown in Fig 9.

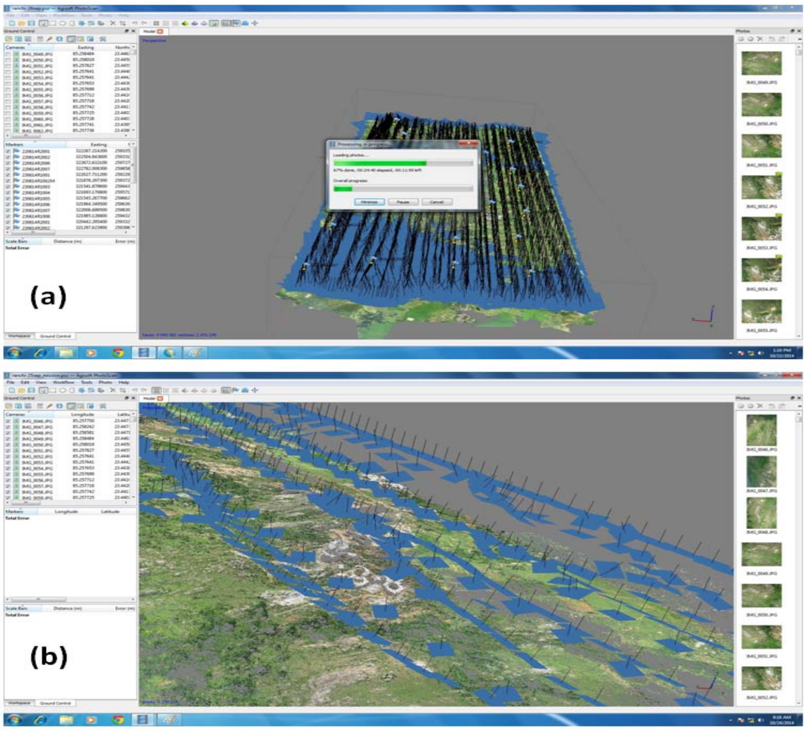
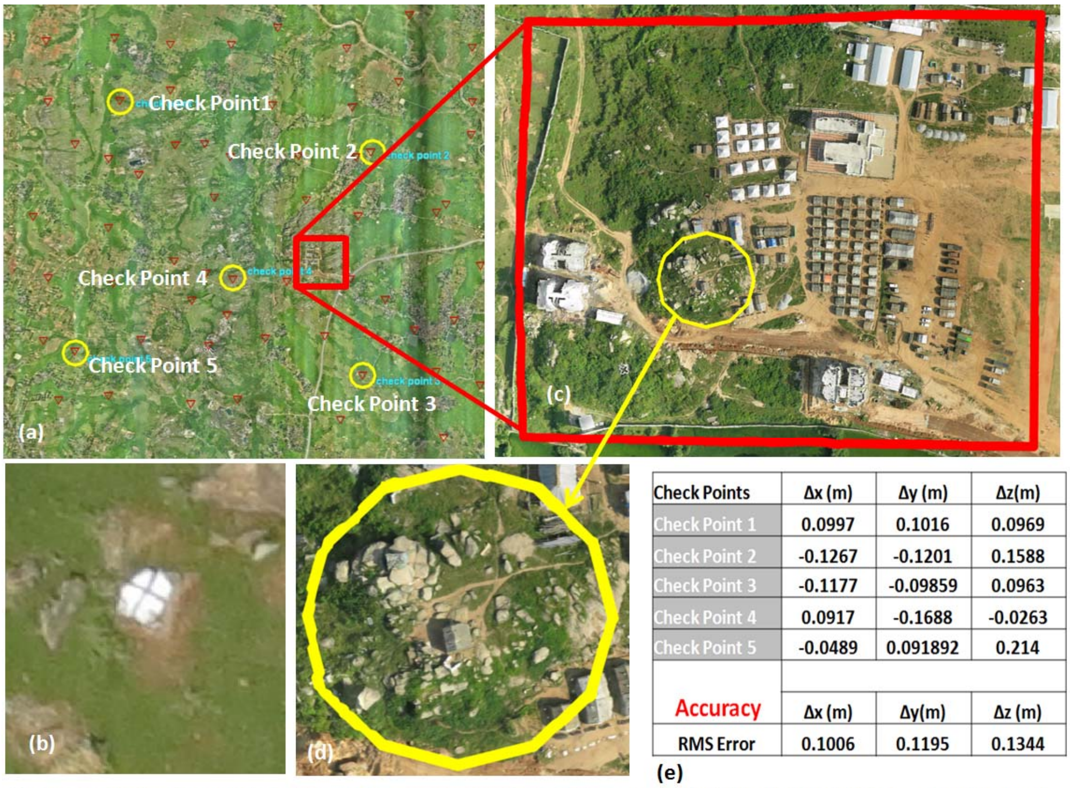


Fig 6 : (a) Processing window in Agisoft Photoscan Professional software (b) Dense Point Cloud with Camera Image foot prints



Check Points	Δx (m)	Δy (m)	Δz(m)
Check Point 1	0.0997	0.1016	0.0969
Check Point 2	-0.1267	-0.1201	0.1588
Check Point 3	-0.1177	-0.09859	0.0963
Check Point 4	0.0917	-0.1688	-0.0263
Check Point 5	-0.0489	0.091892	0.214
Accuracy	Δx (m)	Δy(m)	Δz (m)
RMS Error	0.1006	0.1195	0.1344

Fig 7 : (a) Orthophoto (pixel size 5cm) processed using UAV images with GCPs & Check Points superimposed (b) Visualization of one GCP Marker on processed orthophoto (c) & (d) Zoomed View for visualization of Horizontal Resolution (e) Accuracy & X, Y, Z RMS Error Table for 5 Check Points used during Processing.

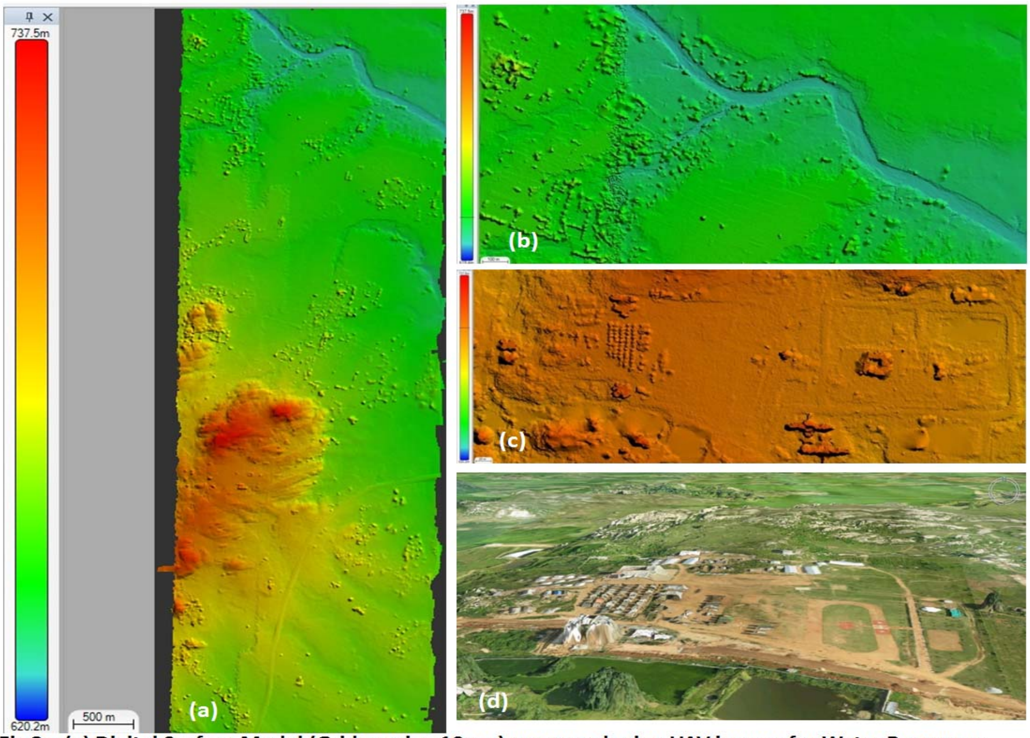


Fig 8 : (a) Digital Surface Model (Grid spacing 10 cm) processed using UAV images for Water Resources Applications (b) & (c) Zoomed View for visualization of Vertical Accuracy (d) Orthophoto Draped Over the DSM

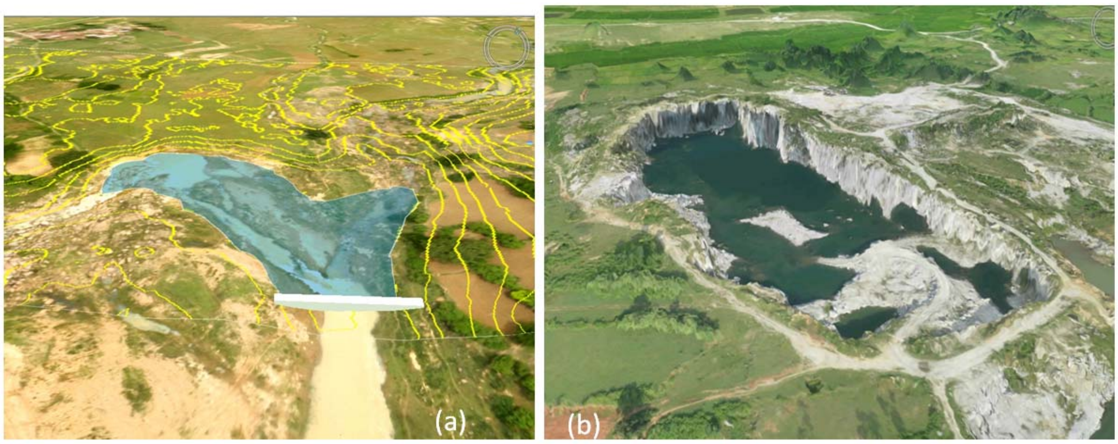


Fig 9 : Digital Elevation Model draped with orthopohoto analyzed for Water Resources Applications (a) Planning of 1m Check Dam & (b) use of abandoned open Mine pit for storage of Rain Water

5 Case Study 2 - 3D City Building

Objective of the study: To create virtual 3D models of habitation area for 3d land and property information management.

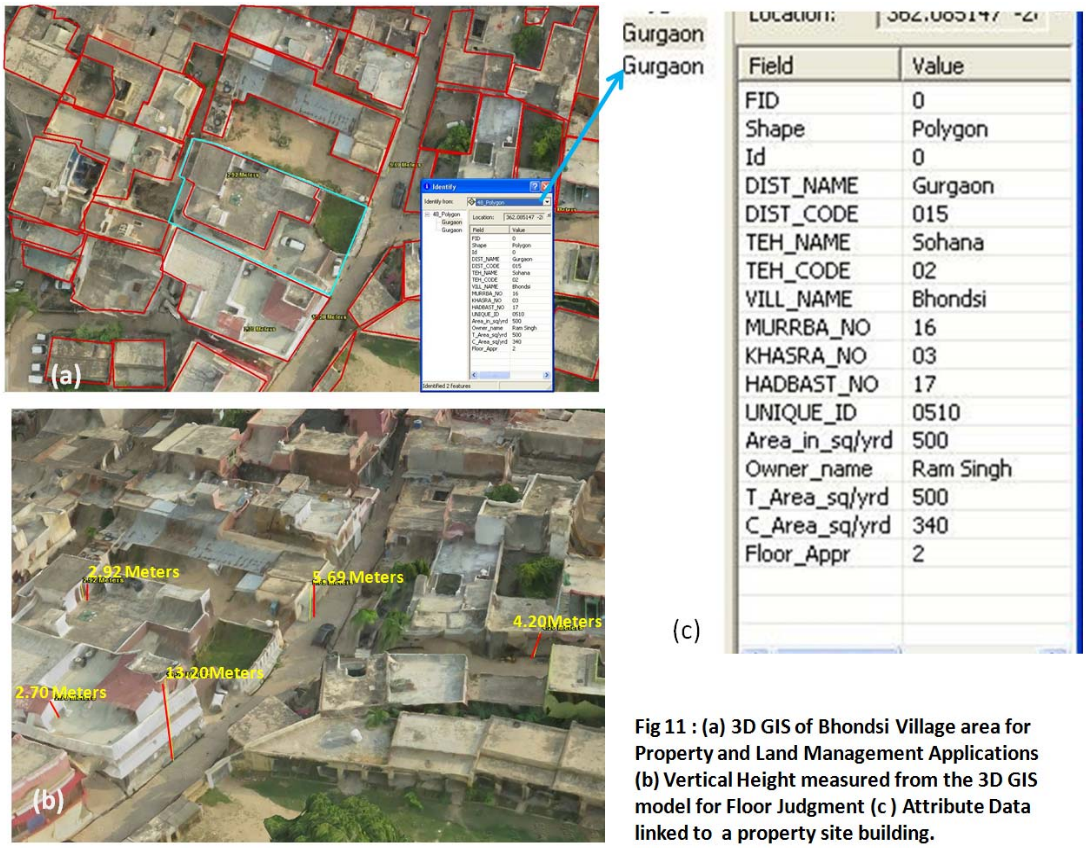
Area of the interest: A rural area named as Bhondsi well inside the growing city of Gurgaon in Haryana state. 1 sq km of area was taken as pilot study for the proof of concept.

Materials & Method:

UAV System and sensors used & Image acquisition:

For capturing the buildings and its facades generally a Rotary wing (Quad copter) UAV is deployed for capturing images with high resolution details but its limitation is that it has very short endurance time, and requires a lot of missions/efforts to cover large areas. Since the requirement is only to create 3d GIS information model which can produce property information and to check the authorized level of construction viz. height of building and thereby number of floors constructed and approximate assessment of the construction deviation and alteration from the approved plan. Although aesthetically it was not charming to visualize the village habitat / building model but the purpose was achieved. We also intend to cover large areas which could become commercially viable and can replace the traditional manned aerial platforms meant for such applications. We have used here a fixed wing UAV system along with all other components as specified in case study1 above. The area was subjected to aerial coverage through the same Mission Planner software with same specification of overlap with slightly less camera shooting rate, but at low altitude of around 120m from ground level. Since the building had to be covered from all directions we deliberately planned two types of mission, one with east-west direction and other with North – South of the flight. Here we got two sets of images just the double the normal flying. The purpose was to cover complete information of a building. After the image acquisition, DGPS observation was done to provide 5 Ground Control Points (GCPs) to get accurate coordinates to be used for processing to achieve desired accuracy. Photogrammetric processing was done using Skyline City Builder PhotoMesh software to process two sets of images in a single project to create a direct textured 3D building model of the area.

Fig 10 : (a) 3D Building of Bhondsi Village area processed using UAV images through Skyline City Builder and Photomesh software for Property and Land Management Applications (b) Zoomed Top View of the 3D Model of Bhondsi (c) & (d) Isometric View of few buildings in Bhondsi.



Field	Value
FID	0
Shape	Polygon
Id	0
DIST_NAME	Gurgaon
DIST_CODE	015
TEH_NAME	Sohana
TEH_CODE	02
VILL_NAME	Bhondsi
MURRBA_NO	16
KHASRA_NO	03
HADBAST_NO	17
UNIQUE_ID	0510
Area_in_sq/yrd	500
Owner_name	Ram Singh
T_Area_sq/yrd	500
C_Area_sq/yrd	340
Floor_Appr	2

Fig 11 : (a) 3D GIS of Bhondsi Village area for Property and Land Management Applications (b) Vertical Height measured from the 3D GIS model for Floor Judgment (c) Attribute Data linked to a property site building.

6 Case study 3 - 3D Models of Heritage site

Objective of the study: To obtain accurate high resolution 3d reconstructed model of Heritage sites for their Digital preservation and creation of National library of Heritage models for future repairing / recreating if damaged in due course of time.

Heritage Model of Interest: One Pilot model of about 20 ft height , a statue of Lord Mahavir Jain (Lord of Jain Religion) situated in Delhi was selected for proof of concept and to test the capability of reconstruction and its quality perfection to its originality.

Materials & Method:

UAV System and sensors used & Image acquisition: The Quad copter micro-UAV specified in table 2 was chosen for imaging the model. The copter was allowed to hover around the model at an altitude of 15 meter from ground. The Canon S100 consumer camera was used for imaging. It was mounted on a Gimble which can allow angular adjustment for viewing desired target. The Mission planner software was used with automatic setting of capturing about 60% overlapped imaging with its vertical takeoff capability. About 9 Missions were performed with sensors tilted at different view angles in order to ensure enough coverage of the statue. The total flight time was 30 minutes. Apart from the missions carried out, a few terrestrial pictures were captured from the same camera moving around the statue on ground. It was ensured that each part of the model gets imaged at least on three photographs while terrestrial photography was done. Around 267 photographs were obtained in total, out of which 183 photographs were shot at the target and rest were out of the target due to uncontrolled flying.

Fig 12 : (a) & (b) Front & Side View photographs of Mahavir Jain Statue taken from Ground using Canon S100 camera (c) & (d) Aerial photographs of the Statue taken from Canon S100 mounted on Quad Copter Micro-UAV

Photogrammetric processing: All the photographs were subjected for photogrammetric 3D reconstruction processing algorithm through AgiSoft Photoscan Professional. To achieve good reconstruction results masking was done by intelligent masking tools of the software for its all irrelevant elements viz. background, accidental foreground etc on the photos. Then Photo alignment, build dense point cloud and build mesh tool were run one by one with setting all relevant processing parameters. The most important phase of processing was Build texture which was meant for building of a texture library files of the model captured in the photographs. Finally the model was exported into one of its open format named as Collada (.dae) format compatible to many 3D visualization softwares like Google sketch up, Blender & Skyline Terra Explorer.

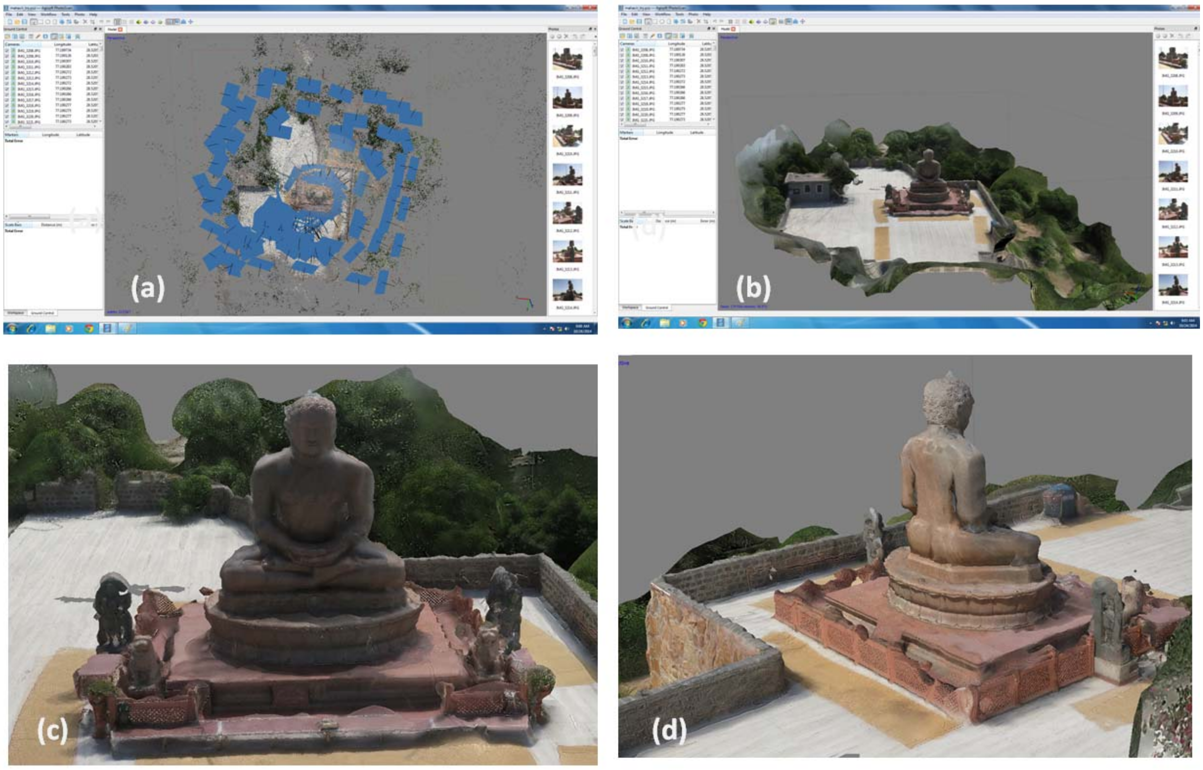


Fig 13 : (a) & (b) Processing window with Dense point Cloud and camera foot prints & textured model of the Mahavir Jain Statue (c) & (d) Zoomed view of the textured model of Mahavir Jain, Front and side view.

7 Observations from the case studies

7.1 Case study 1: Water Resources Applications

From the following details of the tasks carried, out we compare the costs of imaging through different platforms:

Imaged area	60 sq km
Flight operating time	20 hrs (49 missions in 7days)
Number of images acquired	Over 20,000
Image resolution	5 cm
Positional Accuracy : Horizontal & Vertical	10 cm & 15 cm
DGPS Survey time	40hrs @8hrs/day observations
No. of GCPs	60
UAV used	one fixed wing
DGPS Operators	3
UAV Operators	3
Ground Vehicles	2 SUVs

Table 5: Details about the image acquisition and processing results of the case study 1

The cost of carrying out above activities is around $2000 including overheads and logistics. The cost of satellite stereo data for the same area would be around $2400 which is much higher. Also, the cost of flying manned aircraft would be far more expensive than above in addition to huge initial investments and needed logistics support.

7.2 Case study 2: 3D City Building

In this task only 20 minutes of UAV flying was done to image 1sqkm area for creation of 3d city model at a very nominal cost. Whereas this is not doable with satellite imagery and, manned aerial imaging for small areas is not feasible due to huge cost implications. We can fly large extent of areas and create 3D city models of any single geographical extent looking at the average administrative span of Indian habitat agglomerations except a few metro cities. Using a manned aircraft, we can achieve the same but again it will cost higher in addition to administrative and logistic hassles.

7.3 Case Study 3: 3D Models of Heritage site

From this case study, it is seen that for creating high definition detailed 3D models of heritage Monuments, sites and objects close range photography and hovering around the site is necessary supplemented with terrestrial photography. We cannot recreate such models using satellite images and manned aircraft photography as these platforms cannot be operated in this manner.

In all these cases the high volume of digital data can be processed using high-end workstations. Thanks to innovative computer technology and algorithms based on applied mathematics, that enable us to process these image data in considerably short time. The GPU enabled workstations that used in the above 3 case studies took only 80hrs, 6hrs & 2hrs processing time respectively. The cost of these workstations & software also add very little overhead cost for accomplishing these jobs when compared to the cost of traditional photogrammetry software cost.

The quality of 2d & 3d information from the output obtained from these case studies is much superior to the satellite data. We are getting orthophotos of GSD 5 cm and accuracy around 10 cm in x & y. Also, we are getting a Digital Surface Model and 3D point cloud data with vertical accuracy of 15 cm. This would be an added advantage when we make choice of the platform.

Another advantage of the UAV platform has is that the flexibility of operation i.e. we can execute our mission at anytime from anywhere within few hrs of preparation time. Whereas for manned aircraft runway is required and it also requires a lot of preparation time. Also, it is dependent on broad range of clear weather window, for example at least for a week long period. But UAV can be operated if few hrs of clear weather window within a day is available. But for satellite the imaging time is fixed. It cannot be optimized with respect to weather conditions and cloud coverage like UAV platforms.

One more advantage the UAV platform allows us is that of flexibility to frequent change of sensors depending on applications like multispectral, hyper spectral, Lidar, and SAR etc. At times Platforms within the UAV like fixed wing or Rotary wing can be selected as we did in case studies 1 and 3 above.

Many applications like monitoring of infrastructures viz: highways, flyovers, bridges, construction sites, mine quarries, etc require repetitive collection of information. UAV is a perfect cost effective platform for such type of applications over the other two platforms. It can fly with a greater temporal resolution and also flying can be customized by the user's requirement.

8 Earth Observation Platforms

The two Erath Observation platforms, the satellite and manned aircraft provide images from which we can acquire geo-information. Use of these platforms has a long history and series of developmental phases in on-board sensor technology. These sensors are being providing images with spatial resolution ranging from few hundred meters to sub-meter for different applications catered by the geospatial community. Also they are capable of providing multispectral and panchromatic images simultaneously according to the sensors mounted on -board. When it comes to non-terrestrial platforms we do have the choice between these two platforms that are best suited to the traditional domain of topo-mapping and thematic mapping. Markets for geospatial technologies include nowadays applications in Insurance and Risk management, Mitigation of natural and man-made disasters, Real estate, Location-based Services, Environmental monitoring, Vehicle navigation, Homeland security and many more.

Now Mapping is going beyond this traditional way, trending towards multi dimensional, very high resolution and content based applications. Also, the above two platforms have realized few drawbacks looking at the advancement of data requirement. The issues are huge initial costs; cost of operation for small areas, custom temporal coverage and finally the most important is the quality of data. For this reason the third platform UAV becomes effective best suited for the modern and advanced mapping requirement. Based on the image acquisition as for the three example case studies above, few advantages are highlighted above for comparison with other platforms and to make the selection out of any one of the platforms depending on various application factors..

9 Major Legal and Administrative issues of UAV Operations

The major issues of UAV technology are "Responsibility", "Liability", "Insurance" and "Regulations" associated with a UAV operations on different territories.

There are four entities play vital role in this regard which are "Local Aviation Authority", "Operator", "Manufacturer" and the affected "Population". Out of these the operator plays the central role of taking all the responsibility. He has to ensure the legalities of the operation as per the prevailing orders of the concerned authorities. He is the key person who has to ensure against any manufacturing defects, Airworthiness, Pilot's proficiency & conduct, Insurance matters etc. The operator should honestly report the occurrence of accidents, misconduct if any, gravity of the accidents and can help policing the miscreants. Based on his input and such experience, every territory has to formulate comprehensive regulations & standard operating procedure to harmonize the UAV operations.

The next issue is the insurance which has to be considered based on factors like weight of the aircraft, greater speed, non segregated environment, populated areas, risk assessment, damages to third party, claims history etc. Collecting all the facts based on the above key elements through various forum & questionnaires, one could propose an Insurance framework with a balanced financial liability on either party.

On the aspects of security concepts like unlawful interference for crime and terrorism, cyber and communications vulnerabilities also needs to be considered in framing the regulation.

Another the most important & practical view should be on considerable human errors in Micro-UAV operation, the results of human errors in the form of Slips and lapses, Mistakes, Violations etc during the UAV mission. Thus actively work on a safe community means to take responsibility, share knowledge, and learn from others.

The issue of UAV operation is now under discussion by US Public and International media on privacy of common citizens which is hindering the legitimate use of UAVs for mapping and surveying applications. The same arguments have been made in the past about privacy concerns from traditional aerial photography also.

For now, flight restrictions in most of countries are effectively suspending large-scale commercial UAV use while these privacy issues and some legitimate air safety issues are being worked out. It is likely that future rules and regulations will include some form of competency testing and standard collision avoidance policies and procedures. Many International organizations, associations and authorities like European Aviation Safety Agency (EASA), US Federal Aviation Administration (FAA), and Joint Authorities for Rulemaking of Unmanned Systems (JARUS) etc are conducting conferences & meetings to prepare firm globalization rules for International to National and Regional level UAV operations.

10 Other Challenges yet to be resolved

Apart from the above major issues related to responsibility, liability, insurance and regulations associated in UAV operation as explained above, a few technical challenges we would like to highlight based on our experiences encountered during image acquisition for the case studies presented here.

It is difficult to maintain a constant Ground Sampling Distance (GSD) all over the area when flown over a large extent of area with undulating terrain type as the change of altitude bears an appreciable impact on swath size and GSD. Also, it requires a lot of home work on planning our missions using existing available terrain information before executing final missions on ground. Especially in a relatively high hilly region, the maximum and minimum elevation information must be analyzed and accordingly altitude in the Mission Planner software should be set otherwise there could be a chance of crashing.

Our objective is to create ortho-mosaics with minimal geographic reference errors, but it is observed that processing the images using GPS information from small autopilots or from sensors, achieved accuracy in the range of 10-15 meters only which is not acceptable for large scale mapping projects. The centimeter level accuracy could be obtained only if we use enough precision Ground Control Points (GCPs) distributed over the complete area of interest and should have grid spacing not more than 500 meter. Hence it requires large number of GCPs involving a lot of field activities. This again adds to the cost to the project. Also, it is noticed that the distortion in geometry of images, due to slight turbulence (Roll,Pitch,Yaw) of the micro UAV, gets amplified when flying at low altitude in order to achieve high resolution images. This distortion requires rectification through use of GCPs supplemented by the edited elevation data and Camera calibration data with lens distortion information.

Payload has been one of the limitations of micro-UAVs when compared with bigger UAVs and other manned aircrafts, due to their size. This reduces the option of using multiple sensors and sensors for certain specific applications.

Micro-UAVs are generally lighter than 5 kg which causes the aircraft to be relatively instable and in turn limits the overall control and maneuverability since these run through low energy efficiency smaller motors. In addition to this, wind speed also plays an important role for extremely small aircrafts and therefore, one has to look for a suitable flying window.

The range and duration of flight have been the most significant problems facing Micro UAVs both in past and present. Due to small size of the aircraft, battery power that can be carried is currently very limited. This poses problem and multiple missions have to be flown to cover the target out- turn of the day thereby involving a lot of landing and launching operations. This requires skilled manpower and adds to the risk of crashing. Researchers have been continuously attempting to find alternative energy sources.

Currently, larger UAVs rely on traditional jamming signal codes and encryption codes but the signal to micro-UAV is relatively open to interception. This has been one of the biggest factors that have led to an increased use of bigger UAVs when compared to micro-UAV. However, with shrinking size of transistors, emerging manufacturing techniques, and continued increase of funding, micro-UAVs in the future will have enough capabilities to stay in competition with the bigger UAVs.

11 Future Trends

In the previous Para we have mentioned a few practical challenges which could be resolved in the near future as the UAV industry is developing at a very fast pace and now becoming the key areas of research and development in the technology. This would definitely be our future ventures to succeed in professional use of this technology for geospatial community which may demand replacement of other two platforms.In addition to formulation of comprehensive and cohesive UAV operation regulations, the focus of future research has to be on the following:

In order to eliminate large volume of GCP data collection, the UAV system must add precise attitudinal data to imagery, allowing for direct image geo-referencing. We can use a technology delivered now 20 Hz V-Map System packaged by Micro Aerial Projects L.L.C, a geospatial service provider based in Florida, USA for precise UAV-camera exposure positioning. They have designed a hardware configuration that integrates dual frequency GPS (or optionally, single frequency GNSS) post-processed positioning capabilities with event marking, thus enabling precise positioning of cameras at the moment of exposure. Please refer http://www.microaerialprojects.com/ for details about this product.

We believe that the key technological breakthrough for micro-UAV will be the development of a suitable high energy-density power source. However, research is being carried out on the following areas:(a) Solar energy – In the past, solar energy has been employed on UAVs and in December 2010, QinetiQ Zephyr stayed in air for 14 days straight using solar energy and set a new Record. (b) Laser energy – Researchers have been exploring the use of lasers to transmit energy from a ground station to a photovoltaic receiver at the UAV through a beam director. However, this energy has not been employed yet due to the limited range and low efficiency.

Few important technologies may be felt as factious as of now but could be initiated. They are

a) Sensor fusion- Synthesizing information from multiple sensors for computation tasks

b) Communications-Handle communications from multiple sources and coordinate information.

c) Path planning - Determining the optimal path for flight and adjusting to hazards or attacks.

d) Cooperative Tactics – Allowing UAV swarms to communicate and coordinate activities

e) Targeting – Automated processes for identifying and tracking the target (very important development for commercial applications in future)

12 Conclusion

The potential benefits of this technology are that due to its high definition RS data acquisition capability, it suited many applications viz: Cadastral mapping, Volume Estimation, Inspection of Infrastructures, 3D reconstructions of archaeological sites, cities etc. Another added advantage of this technology is that it's easy reach for change of sensors allows to collect RS data not limited to fixed /visual spectrum only but could be extended to thermal and hyper spectral bands. The accuracies in these applications are as high as 3cm in horizontal and 10cm in vertical when the use of Ground control Points are extensively done. The maximum quantum of image processing up to 8000 images with 10cm GSD could be possible as we did in our case study-1. Other products like high accurate orthophotos, DSM, DTM and its derivative products could also be generated easily.

In all the cases it is highlighted that Micro-UAV imagery produces higher accuracy with better economy. The other important applications like precision agriculture, Disaster management, Oil and Gas Pipeline monitoring, Construction work, Earth movement and excavation, Laying of pipes and cables, erection of buildings, soil upheaval and erosion, water logged surfaces, plantation of shrubs and trees, discoloring of vegetation, forest fire detection / forest management, atmospheric sampling missions and landscape mining could also be done through this technology.

There is an increasing use of Micro UAVs for photogrammetric data collection which enables a "Third Road" in Earth observation as justified. Also it is now realized that it complements the conventional aircraft systems and satellites & provide a good alternate to High-resolution photogrammetric applications. These systems could be used for productive work with effective commercial viability but, should be dealt with responsibility, with harmonized operational and legal framework. Due to such restrictive constraints, UAVs are not being commercially operated in many countries. However, it has filled a latent gap for photogrammetric application and has huge commercial & technical potential that has to be exploited.

Rightly we can say: Micro-UAVs are an alternate route to Earth Observation for Geospatial Community.

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Creation of an online GIS for the "Blautopfhöhle", one of Germany's largest caves [1]

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KEYWORDS: Blautopfhöhle, Online GIS, Cave, ArcGIS Online, ZEB1, mobile laser scanning

ABSTRACT

The Blautopfhöhle, with 32.860 feet (10,015 m), is the third largest cave in Germany, with a significant amount of unique minerals. The famous spring "Blautopf", with the specific blue colour, was for many years the only entry to this cave.

The "Blautopf consortium" is a group of geologists and divers who investigated in the cave. During the exploration their aim was to document the extension of the cave, but also the minerals. To achieve their targets the explorers made a traverse through the cave with compass and digital range finder. Afterwards the travers was visualized with a graphics editing software called "CorelDraw X5". However, this method of mapping the cave was disadvantageous, since it didn't enable the explorers to work on the map at the same time.

To make it possible for all the explorers to document their work independently and to share the results in a comfortable way to a wide audience, the whole documentation was moved to HFT-Stuttgart, where, within the framework of a bachelor-thesis, an online-GIS was created on the platform of ArcGIS Online and with a common data store.

The presentation highlights the functionality given by ArcGIS Online and its map templates, which offer new functionality based on predefined widgets and multi-media integration.

The presentation shows also how 3D-Records were used in the online-GIS and introduces a new mobile laser scanner, the ZEB1, a Hand-Held Laser Scanner which is capable of capturing 3D point clouds, even in areas with no GPS.

1 Introduction

"Blautopf" stands in English for "Bluepot". The spring "Blautopf", which is located in southern Germany, is not only famous for its specific blue color, but was also for many years the only entry to one of Germany's largest caves.[4]

Figure 1: The "Blautopf", the entry to the cave

[1] Source Summary of Bachelor Thesis by George Dilk

The Blautopfhöhle means "the Bluepotcave" and it is 32.860 feet (10,015 m) long, which makes it to Germany's third largest cave. Not only the size is impressive, but also the large amount of unique minerals the cave hosts. [5][6]

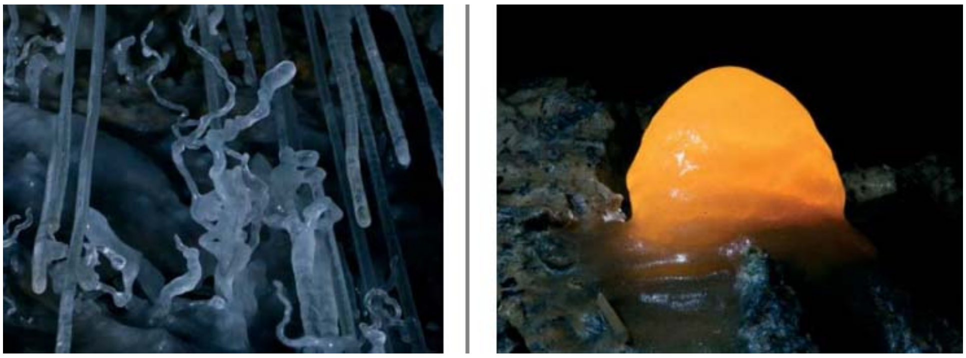

Figure 2: Minerals found in the cave.

The "Blautopf consortium" is a group of geologists and divers who investigated in the cave.[12] To gain scientific knowledge, the "Blautopf consortium", in partnership with Landesamt für für Geologie, Rohstoffe und Bergbau (State office for geology and mining Freiburg) decided that the cave had to be investigated and all of the minerals which were located in the cave had to be analyzed and documented.[7] To achieve their targets the explorers made a traverse through the cave with compass and digital range finder. Afterwards, the traverse was visualized with a graphics editing software called “CorelDraw X5”. However, this method of mapping the cave was disadvantageous, since it didn’t enable the explorers to work on the map at the same time.

It was important to make it possible for all the explorers to document their work independently and to share the results in a comfortable way to a wide audience. Because the mapping of the cave is not finished yet, the Online-GIS had to provide the possibility to extend the map. At the same time, the GIS had to be easy to handle for users without any GIS-Experience. The whole documentation was moved to HFT-Stuttgart, where, within the framework of a bachelor-thesis, a common data store was created and afterwards moved to the ArcGIS Online platform.

This document highlights the functionality given by ArcGIS Online and its map templates, which offer new possibilities through predefined widgets and multi-media integration.

1.1 The mapping method in the cave

In 1957 a diver found on the bottom of the "Blautopf" the entry to an underwater-cave [12]. But it was not until 1985 that the first air filled hall of the cave could be discovered. Ever since the cave was investigated. [3]

The "Blautopf consortium" was using the following method to investigate the cave: at first, they created an initial point with global coordinates (Gauss-Krüger) and from there on, a traverse through the cave could be started. The instruments to create the traverse were a compass and a digital range finder. With the compass the traverse could be oriented north. The measurement protocol included azimuth, affection and length.

1.2 The previous procedure to the creation of the map

After each survey-operation, the traverse was calculated and visualized by the cave mapping software "Compass".

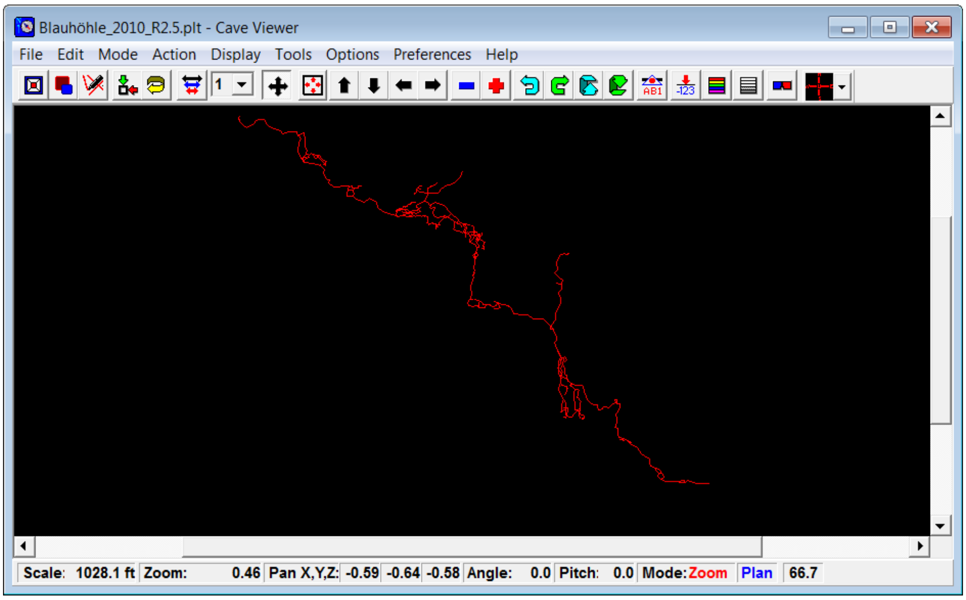

Figure 3: The visualized traverse in "Compass", after the calculation and visualization was done.

Afterwards, the traverse was conversed to CorelDraw X5, which is a graphic editing program similar to PhotoShop. On the base of the traverse, drafts and photographs, the cave could be sketched in CorelDraw. The result was a large graphics file which included the map.

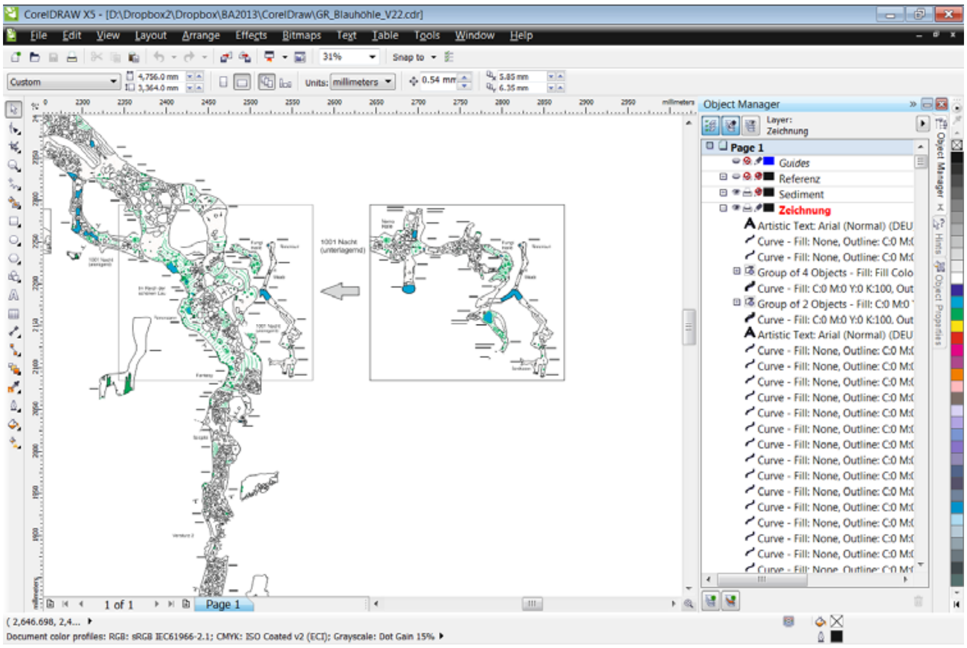

Figure 4:The The result in CorelDRAW X5

1.3 Transition to GIS

To move the sketches to ArcGIS Online, it was possible to export the sketches as dwg. AutoCad-File from CorelDRAW. The dwg. AutoCad-File included the map in a vector format.[2] But ArcGIS Online works only with geo-referenced and classified data. Therefore, to move the data to ArcGIS Online, it had to be prepared. In order to do so, ArcMap (a GIS-Environment) was used to visualize the data, but also to apply general and special tasks.

The objects in CAD, a drawing software like CorelDRAW, were not organized in classes. By the transition of this data to ArcMap, four classes based on the type on geometry were created automatically. The result of transition were accordingly four classes, which included all the objects, but with redundancy. If this result would be transferred into ArcGIS Online, the result would be the same as in the image beneath to see.

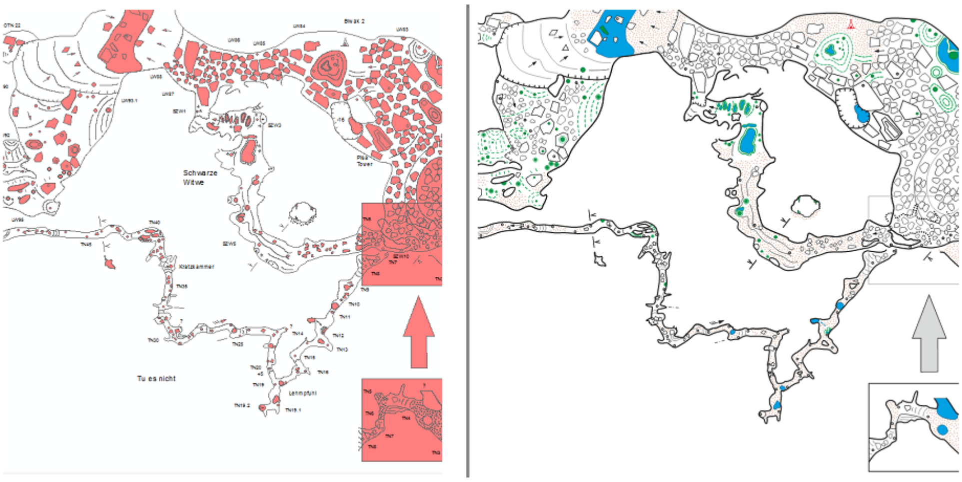

Figure 5: The result of transition would be the same as in the left image to see (CorelDRAW right).

The result of transition would be the same as in the Image 5 to see, only four classes, which contained all of the objects redundantly. Four classes would be only four legend entries. Therefore a database with more classes had to be created and the objectives distributed, before it could be moved to ArcGIS Online.

One of the classes, the class "Polyline", included all the objects. To avoid redundancy, the other three classes were deleted. Later, some of the objects from the class "Polyline" had to be transferred into suited geometry types, but this was easier to process than to work with four classes.

The class "Polyline" had thirty-four attributes, which were created by CorelDraw and included properties such as color and line width, which are necessary to draw the object. It is interesting to note, that out of this thirty-four, only three of them had different values.

OBJECTID *	Shape *	Entity	Layer	Color	LineWt
1397	Polyline	Ellipse	Zeichnung	250	50
1398	Polyline	Ellipse	Zeichnung	250	50
1399	Polyline	Ellipse	Zeichnung	250	50
1400	Polyline	Ellipse	Zeichnung	250	50
1401	Polyline	Spline	Zeichnung	3	35
1402	Polyline	Spline	Zeichnung	114	35
1403	Polyline	Spline	Zeichnung	114	35

Figure 6: The class "Polyline" and its three properties with different values.

On the basis of these three properties, it was attempted to make the classification automatable by using ModelBuilder. However, because the map in CorelDraw had only the purpose to visualize the extension of the caves, the objects were not considered to be distributed on classes.

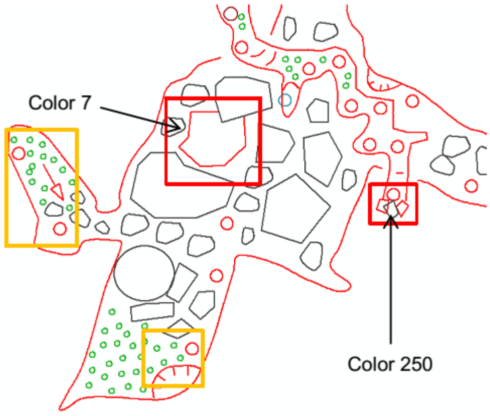

Figure 7: For the same kind of object, "Stone", different colors were chosen (here 250 and 7). But also different kind of objects were described by the same attributes (here arrows and boundary in orange).

Therefore, because the values of the attributes were not chosen systematically, the classification couldn't be done completely automatable. Because of that, the classes, created automatically with Model Builder, were edited individually.

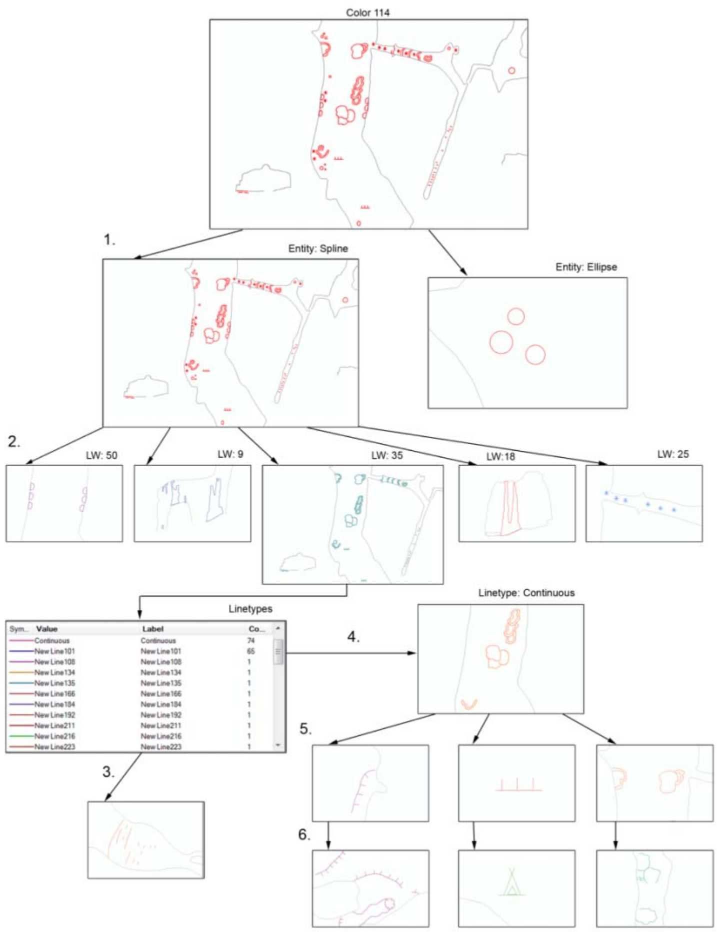

Figure 8: Differentiation of the objects with color 114.

Additionally, the geometry of some classes had to be edited to convert the geometry of these classes into the right type. This could be done completely automatable by ModelBuilder.

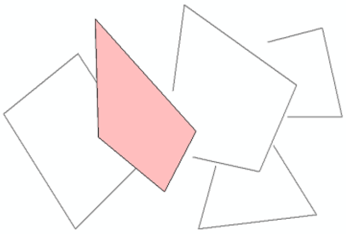

Figure 9: The not red objects had to be closed, so the geometry type could be recognized as polygon.

The last step of the preparation was the geo-referencing of the classes. Afterwards the created database with the classes could be imported into ArcGIS Online.

2 Import of the Data into ArcGIS Online

The image below shows the situation in ArcGIS Online after the import.

Figure 10: The map is blurry, because the publishing of the exact position of the cave is prohibited.

The Geodatabase has a strict object-structure; it could be published as raster and feature services, so it's therefore completely interactive. It's possible to change the geometry or the attribute-values easily and adjust all properties.

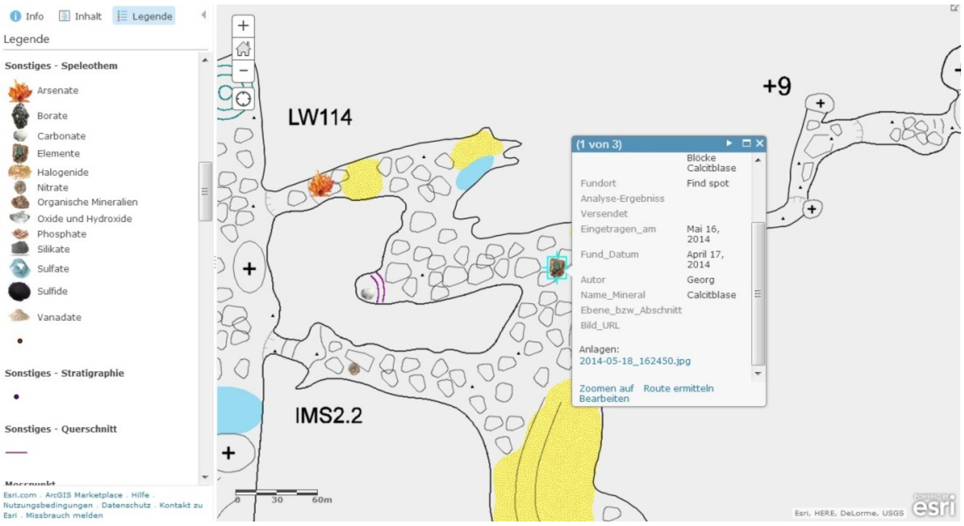

Figure 11: The geometry or the attribute-values can be changed easily. The symbols for the found minerals are adjustable. The legend was matched with the official UIS List for cave symbols.

Before the implementation of the data to ArcGIS-Online, the description, the results of mineral-analysis and the photos were linked to the location by lines, but in some cases the photos overlapped the map and with more finding it became more and more confusing.

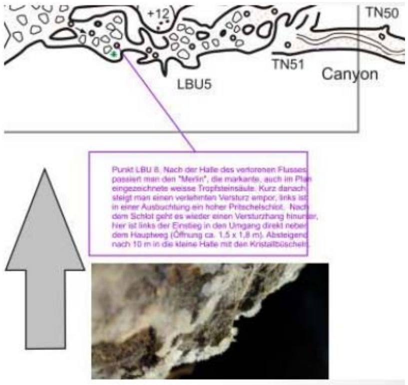

Figure 12: Description, the results of mineral-analysis and photos in the CorelDRAW-Drawing

In ArcGIS Online pictures can be uploaded directly to ESRI-Servers or the URL can be linked directly to the objects. Furthermore, it is not necessary anymore for the researchers to use CorelDraw, they can upload the traverse as a Shape-File directly from "Compass" to ArcGIS Online and expand the map.

3 Visualization of the cave

The team of researchers was also interested in how a 3D-Scanner could be used in the cave. It was possible to use a new mobile laser scanner, the ZEB1, which is a Hand-Held Laser Scanner and it's capable of capturing 3D point clouds, even in areas with no GPS.[9] During the bachelor-thesis it was possible to test this device.

Figure 13: The scanner consists of a 2D-Laser, an inertial measurement unit, data logger and a battery.

In contrast to terrestrial laser scanners, the ZEB1 doesn´t have to be positioned to create a point cloud and it's also highly portable. To scan, a loop through the area to survey has to be made. During the movement the scanning head has to be animated. This motion combined with the records of the IMU, which is in the backpack, provides a continuous 3D-Point Cloud.[10] This is possible because the ZEB1 compounds segments of the scanned area through overlapping features.[11] Therefore is the ZEB1 especially practical in environments such as caves, but would have its difficulties in areas such as tunnels, which are lacking on features. [8]

Maximum range	Up to 30m in optimal conditions Typical max range 15-20m
Points per scan line	1080 (0.25° interval)
Field of view	Horizontal 270°, Vertical 120° (approx)
Scan rate	40 lines/s 43200 points/s
Scan range noise	+/-30mm
Laser safety classification	CLASS I Laser Product (21 CFR 1040.10 and 1040.11)
Laser wavelength	905nm
Operating conditions	Temperature 0° C to +50° C Humidity <85% RH
Power supply	12VDC +/-10% approx. 1.5A
Weight	Handheld unit 0.66kg Carry case and contents 3.6kg
Dimensions	Handheld unit 60x60x360mm Carry case and contents 470x220x180mm
Battery life	Approximately 5 hours continuous use

Figure 14: Further specifications of the ZEB1

During the test a large area of the test environment could be scanned. For post-processing the data had to be uploaded to the manufacturer server. As a result, the user gets cohesive point cloud in LAZ-Format and in different versions (raw, time-colored, shaded…).

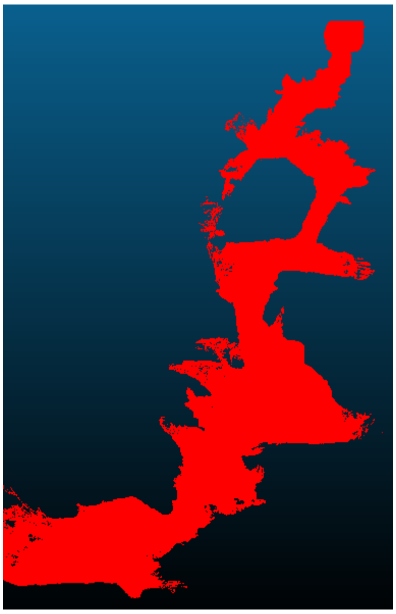

Figure 15: Raw point cloud

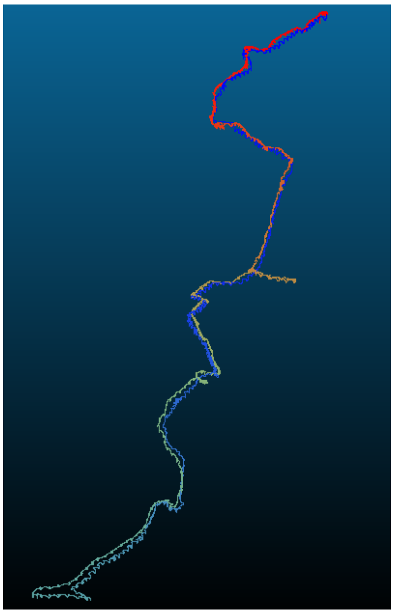

Figure 16: Trajectory of the scanner through the area

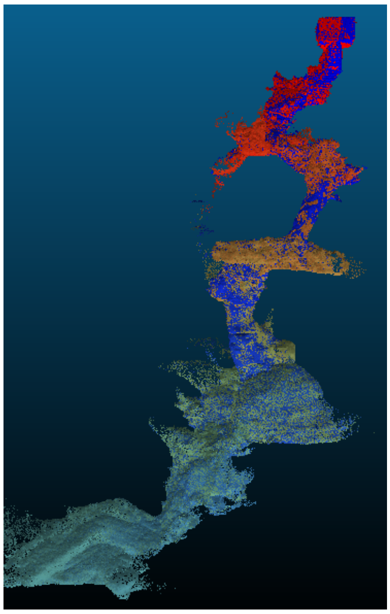

Figure 17: Colored by time

The manufacturer of the ZEB1 affirms that it has a distance-accuracy of 1-3 centimeter. The analysis of the created point clouds delivered a result of one centimeter.

For the "Blautopfhöhle" for example, it would be possible to use parts of the made point-cloud to create cross sections for the important parts of the cave.

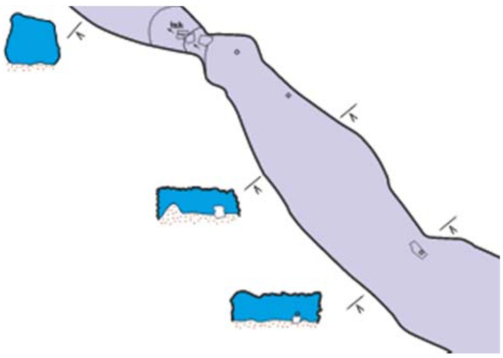

Figure 18: Cross-sections within the map (CorelDRAW and ArcGIS Online).

It would be possible to abandon this cross section inside of the map and replace them through actual visualization of cross-sections made out of the ZEB1-Pointclouds.

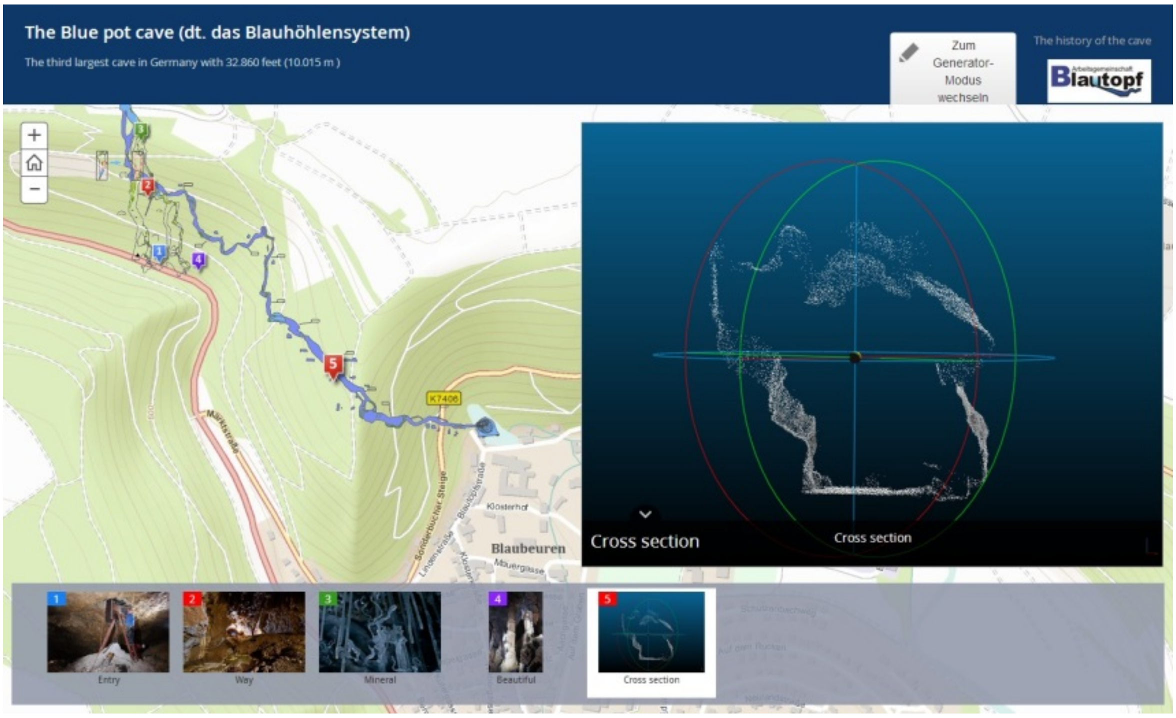

Figure 19: Cross Section made out of the ZEB1-Point cloud and linked to a location in the online-GIS.

4 Conclusion

It was possible to transfer the digital drawings from CorelDRAW to ArcGIS Online. Despite the fact that the automatable creation of the classes was not successful, a geodatabase could be created. In the end, the main objective, the transition of the data into an online GIS and the creation of a GIS in which all the explorers can work on the map at the same time, was successful.

ZEB1 has shown that it is a light and a low-cost device to provide point clouds. This point cloud contains information which can be used in the online GIS in different ways.

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Use of RS and GIS for Flood Risk Assessment: A Case Study of Wangchu River, Bhutan

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KEY WORDS: Flood risk assessment, GLOF,climate change, hyrological analysis, manning's coefficient, overlay analysis, hazard risk.

ABSTRACT

In accordance to the framework of Disaster Management Act of Bhutan, flood risk assessment was carried out for Wangchu River in capital city leveraging the available Remote Sensing (RS) and Geographic Information System (GIS) data in a way to reduce the impact it causes on people and the environment. The city with a population of 0.12 million is annually affected by flash flooding and in order to assist the emergency response service division, insurance companies and the local municipal authority, the work to perform flood risk assessment was initiated. Bhutan is also esposed to Glacial Lake Outburst Flood (GLOF) considering the severe damage incurred both to nature and human lives in the year 1994. It is therefore vital to safeguard our communities against the impact of climate change disasters such as floods, earthquakes, landslides, cyclones etc. Moreover there is no comprehensive studies on flood risk in the country, it was felt crutial to perform flood risk assessment using appropriate tools.

The work was made through hydrological analysis for the past 10 year's annual peak rainfall data. The data was analyzed for calculation of flood frequency and return periods adopting the commonly used Gumbel distribution. The hydraulic model program Hydrologic Engineering Center River Analysis System (HEC-RAS) was deployed for flood modeling due to the fact that the program is open source and it's geometric data input and simulation can be performed in GIS environment. High resolution Digital Elevation Model (DEM) generated through photogrammetric processing of Geo-Eye satellite imagery was the main input data. The geometric data required for modeling was then extracted from DEM using HEC-GeoRAS, an extension of ESRI Arcmap. Hydrologic data like river width, river bed slope and river depth were collected through field measurements. The manning's coefficients were then estimated for various land cover types which were obtained from processing the remotely sensed data.

The hazard assessment for different return periods was done based on the depth of flooding. The hazard extent map produced was overlaid on the topographic base map to delineate the elements exposed to different degree of flood hazard. The vulnerability analysis was carried out based on the recent census and building data available. Considering the vulnerability of population and duildings, the cost of the elements at risk were determined by estimating the initial cost of construction adopting the existing plinth area rate method.The flood risk zone map as a function of hazard and vulnerabilty for different return periods for the city was achieved in combination of hazard and vulnerability through weighted overlay analysis in ESRI ArcGIS environment.

The GIS based risk zone maps which is easily rediable, rapidly accessible is currently in used by the planners as base information for land use planning. The risk map is also extensively utilized by the engineers in support of disaster preparedness and mitigation activities. Preparation of flood risk map for Wangchu river was one of the crutial steps for implementing non structural remedial measures. Risk assessment and evaluation of the affected properties can now be performed based on the flood risk and hazard information derived through this work. The database now serve as an important tool in various phases of disaster management cycle both at national and local level.

A Habitat Model for Wildcats

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ABSTRACT

Because biodiversity is key in providing ecosystem services and contributes enormously in the effort for a sustainable planet where humans and all the different species can coexist, habitat models are essential. This article presents a habitat model for wildcats based mainly on landuse information and other important requirements for wildlife survival. This has the possibility of being applied to other species of similar characteristics to wildcats. The model was performed for the state of Baden-Wurttemberg (BW), Germany. A set of geoprocessing tasks -whose distance parameters were taken mainly from telemetry studies- were carried out and the tool Model Builder from ESRI was used. The resulting suitable areas for wildcats were analysed and not surprisingly it was found that a notable amount of potential habitat area is located in forest landuse specifically in the Black Forest region. From 12300 km2 of potential habitat, 62% are located in forest and 35% is constituted by agricultural uses. In addition, 47% of the suitable area is located in natural parks. Finally, despite scarce information available about wildcats' occurrences a validation of the model yields acceptable results.

KEYWORDS: Modelling, occurences, statistics, corridors, Model Builder, telemetry.

1 Introduction

A model is an abstraction of the reality and its two most important goals are to reduce complexity allowing to be focused in some important characteristics and to make predictions, in consequence, this is applied to habitat modeling. Modeling habitat of a species is a method which has become popular to identify areas for species' conservation. This can become a cost effective tool to identify areas that afterwards, should be surveyed for species presence. Once suitable habitat is identified, then monitoring of species occurrences and population trends can be conducted to help to assess the impacts of development on these habitats as well as the species that live in them.

The increased rate of urbanization which is even higher than the urban population growth makes fundamental the necessity of the city planning. Therefore, urban planners need to include habitat of species into future development strategies. Identification of important habitats plays an important role in core sustainability aspects such as: provision of ecosystem services in urban as well as in rural areas, location of new developments, and protection of endangered species among others.

An example of species under protection is the *Felis silvestris silvestris* commonly known as wildcat which a couple of decades ago was extinct in Europe, only in the last decades, wildcats have slowly recovered in Central Europe, due to total protection and reduced trapping (Stubbe and Stubbe, 2002, Pott-Dörfer and Raimer, 2004). However, the species is still endangered since it faces several issues like: the landscape fragmentation in Europe, traffic mortality, hunting and hybridization (Stahl and Artois, 1995; Pierpaoli 2003; Lecis 2006). Therefore, potential impact on this species has to be assessed and compensatory measures should be considered and included when planning landscape structure.

The wildcat is a cryptic species and therefore detailed information on occurrences; potential occurrences as well as the species habitat preferences are scarce (Stahl and Artois, 1995; Lozano, 2003). Nevertheless, basic requirements such as shelter from weather and predators; food and water for nourishment; and space to obtain food and to attract a mate, are well known to be necessary for the survival of any wild animal (Yarrow , 2009).

The present study aims to develop a model which includes features based on these basic requirements. For such a purpose, extracted features from ATKIS Digital Landscape Model (DLM) were included in a model performed in the Model Builder tool from ESRI. With this model it is possible to predict the distribution of wildcats implementing preferences of the species with vector features' geoprocessing. The model is a versatile tool since for example there is the possibility of modeling other species' habitat with similar characteristics when the specific parameters are adapted to them.

In addition, the given parameters are possible to compliment and modify when significant characteristics are found in the knowledge of the species.

In this article a land suitability analysis is addressed to create a baseline starting point. The model identifies preferences of wildcats and simplifies them distinguishing suitable from unsuitable areas, then the geoprocessing tasks are performed using distances based on literature values. Finally, the results are analysed by making a series of comparisons first between the suitable area yielded with the model and the existing natural parks area, and between the suitable habitat and the forest presence.

2 Methods

2.1 Study area

With a population of 10.7 million of inhabitants the state Baden Württemberg is located in the south western of Germany and covers an area of 35751.46 km². The elevation ranges from 85 m near to Mannheim to 1493 m at the peak of the Feldberg in Black Forest. Climate is mild with temperatures decreasing with the elevation. In the Black Forest the average temperature is 15ºC in July, in January 1ºC. Therefore, snow is frequent in the higher areas which make possible practice of sports as ski. The annual precipitations are between 600 and 1500 mm. Throughout the state there are precipitations during the year.

The Black Forest is an important geographic spot in the state. It is Germany´s highest (1493 m) and largest (6009,2 km²) contiguous mountain range. The Black Forest is less populated than the most other regions of Baden Württemberg, which become it eligible for being habitat of shy species with necessities of considerable and sometimes extended areas.

2.2 Landscape data

Source data is the digital landscape model (Basis DLM) which is organized in a resolution to produce topographic maps in the scale range 1:10000 to 1:25000. It is part of the Amtliches Topographisch Kartograppisches Informationssystem ATKIS.

Basis DLM was used as a filebased geodatabase (1.56 GB) for the whole state of Baden Württemberg, which consisted of 44 feature classes. In this project the main feature to use was land use which had 1.400.000 features.

The habitat model should be developed throughout the area of the Baden Württemberg´ state whose volume of information in vector format is a large dataset. Because of this, most of the model geoprocessing tasks were impossible to execute at once. For dealing with such an issue the datasets size was lightened by mean of carrying out the processes into smaller areas. To have significant sub areas the model was applied to each region of Baden Württemberg (Figure 1) and then the results were assembled together.

Figure 1 Region of Study

2.3 Requirements of Habitat

2.3.1 Model for Wildcats

For modeling the habitat of wildcats the main requirements for survival were taken into account: Cover (shelter) from weather and predators; food and water for nourishment; and space to obtain food, water, and to attract a mate (Yarrow, 2009). The figure 2 illustrates the way how these basic requirements for wildlife are interconnected, the puzzle analogy helps to understand how important is to fulfil all the necessities. All the pieces of the puzzle must be present and in the proper order.

Figure 2 Basic requirements for wildlife

2.4 Habitat model

The habitat model intended to include the four important requirements for wildlife existence: Food, water, cover and space. The landuse information from ATKIS was used as the basic input. The 25 different landuse classes were assessed one by one according to preferences and basic requirements for surviving as well as avoidances. The resulting landuses classes -after discarding some- are considered to be highly likely suitable or unsuitable for wildcats, as it shown in table 1.

Additional categories represent areas or lines constitute barriers for the species and must be part of the model as well. These are intrinsically related to urbanization, human activities and development of human settlements.

Figure 3 summarizes the different levels of information included in the model which involved favorable and unfavorable aspects for wildcats. From telemetry studies it has been widely concluded that the landuse features that influence mostly the wildcat habitat use in Central European are areas: close vegetation in forests, proximity to forest ecotones with water and meadows, and the distance to human settlements and roads (Klar and Fernández, 2008). The diagram intends to depict using the traffic light colors which categories are advantageous for wildcats as well as which ones are an obstacle for the species.

The input variables to use in the model can be conveniently divided into two groups: suitable and unsuitable criteria. These two categories are displayed in the table 2.

A remarkable advantage of Model Builder is the possibility to parameterize the models developed in it. The model analyzed and addressed in this article retrieves a potential habitat model for wildcats, however, in case the model is needed to be extrapolated to other comparable species this could be done before its runtime. For instance, lynxes are roughly felids species of similar behavior and size to wildcats, thus, a model for suitable habitat of lynxes might be yielded if the original provided model parameters were adjusted.

Suitable		Unsuitable	
Nutzung	Land Use	Nutzung	Land Use
Gehölz	Coppice	Flugverkehr	Airport
Heide	Bush	Industrie-und Gewerbefläche	Industrial
Landwirtschaft	Agricultural	Wohnbaufläche	Residential
Moor	Swamp 1		
Sumpf	Swamp 2		
Wald	Forest		

Table 1 Land uses included in the potential habitat model

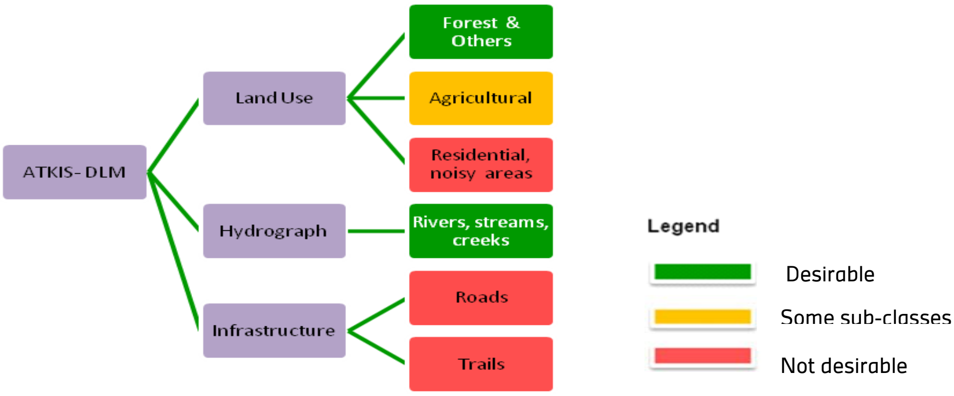

Figure 3 Diagram of Information from ATKIS -Digital Landscape Model included in the model

	No	Criteria	Distances in m	Geoprocessing
Suitable	Area features			
	1	Coppice	300	Buffer
	2	Bush	300	
	3	Forest	300	
	4	Meadows	200	
	5	Swamp 1, 2	200	
	6	Vegetation without commercial purpose	200	
	7	Distance to water	1000	
Unsuitable	Area Barriers			
	8	Distances to villages (residential)	900	Buffer
	9	Industrial	900	
	10	Isolated single houses < 1 ha	0	
	11	Airport	300	
	12	Mixed use, other uses	0	
	Linear Barriers			
	13	Railway	100	Buffer
	14	Roads <2500 vehicles/day	0	
	15	Highway>2500 vehicles/day <10000 vehicles/day	200	
	16	Highway>10000 vehicles/day	300	

Table 2 Bufffers and processes applied into the model

2.4.1 Suitable Features

In the agriculture category is important to notice that not all the uses classified as agricultural are usable for wildcats, only some subtypes play an important role in the model, the table 3 shows them.

Landwirtschaft	Agricultural
Ackerland	Plantations (wheat,corn)
Grünland	Meadow
Streuobstwiese	Vegetation without Commercial purpose

Table 3 Agricultural landuse sub-classes included in the model

To understand the necessities of wildcats regarding the landuses, a rating of each landuse according to the requirements for the animal was performed (Table 4). Here is important to identify which roles play the different landuses in the habitat of wildcats. Forest are fundamental in its habitat, but agricultural spaces as meadows are essential for hunting rodents (Chapman and Ribic, 2002; Sullivan and Sullivan, 2006). Riparian areas within forest as well as edge habitats often provide a higher diversity and abundance of small prey mammals than interior of forest (Doyle, 1990; Gomez and Anthony, 1998; Osbourne 2005). Wet areas represent also important availability of prey (Niethammer and Krapp, 1982; Liberek, 1999; Dieterlen, 2005).

Land use		Shelter	Water	Food	Space
Wald	Forest	5	4	4	5
Gehölz	Shrubs	5	2	5	4
Heide	Bush	3	1	3	3
Moor	Swamp 1	3	5	4	3
Sumpf	Swamp 2	3	5	4	3
Ackerland	Plantations (wheat,corn)	1	1	4	2
Grünland	Meadow	2	4	5	2
Streuobstwiese	Vegetation without Commercial purpose	3	2	5	3

5	Excellent
4	Good
3	Acceptable
2	Poor
1	Bad

Table 4 Main requirements and suitable landuses for wildcats

For wildcats' survival availability of water is crucial. Wildlife species does require drinking water, therefore its habitat must include a permanent water source or the animal must move to areas with water during dry weather, a wildcat will not inhabit areas too far from water, even if food and cover are abundant. It is widely known that most wildlife can survive for weeks without food but only days without water. Thus, this necessity of water must be included in the habitat model to be in accordance with the main requirements depicted in figure 2. Thereby, a combination of the suitable features with water supply is needed. The performed buffer to creeks and streams illustrates that a wildcat wanders long distances to get water. If water is lacking, a rule of thumb would be to provide permanent water sources every 1 km (Yarrow , 2009). The geoprocessing tasks are carried out under the Model Builder tool. The process is depicted in the figure 4:

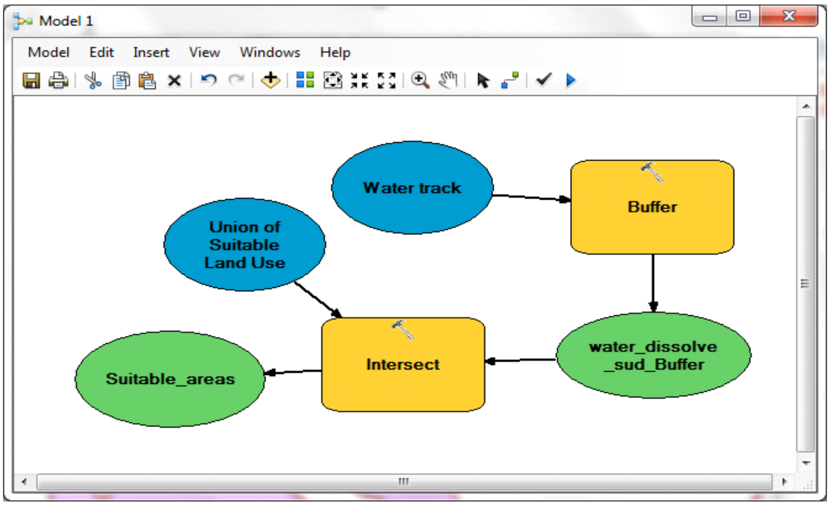

Figure 4 Suitable landuse combined with water presence. The process is shown in notation of Model Builder from ESRI

2.4.2 Unsuitable features

Villages

Despite that some wildcats live in relatively close proximity to human habitation, an aspect in the essence of wildcats behavior is being a solitary species. In the model frame, villages consist of residential and industrial uses and these are considered a strong barrier. Since wildcat is in extreme a solitary species a strong necessity for avoiding all contact as well as human presences are decisive in its habitat. Accordingly, the studies have found that the probability of wildcat habitat use is reduced at distances lower than 900 m to even 1 km from villages. (Klar et al, 2008). In a conservative model, a buffer of 900 m is applied for residential and industrial uses.

However, the different categories included in the ATKIS model have not enough information for determining if a single house could affect the wildcat habitat. It is evident, that there are places which are classified as residential which don't affect significantly the habitat since those have very less presence of humans. Consequently, it can be stated that for performing a very detailed assessment about which areas could represent a threat in the wildcat habitat, more completed information should be gathered. This issue was tackled in the model by mean of executing a revision of some single houses distributed along the territory of Baden Wurttemberg. This was possible using aerial photographs, in which many isolated houses were detected in the middle of the forest and/or in places of neglected activity. Some of these places such as huts or barns are known to be infrequently visited by humans and although many of them have a significant area they cannot be considered a conspicuous barrier for the species. Examples of isolated residential building are set in the figures 5a and 5b.

In spite of the fact that for making a more reliable model detailed studies and considerations are recommendable to be done as was already mentioned, in this model an arbitrary value of single isolated houses whose area was less than 1 ha was considered not to have a big impact in the wildcat habitat as long as these were isolated. So before performing a buffer of 900 m to residential and industrial areas it was necessary to exclude those locations whose area was less than 1 ha.

For achieving this objective two alternatives were studied. The first one had to do with a geographic entity called Ortslage. In it the buildings contained in the ATKIS model which are grouped and covered by a polygon. However, in this alternative was found that no all the buildings were covered. Therefore, many buildings' groups whose accumulated area was bigger than 1 ha were not covered. If a buffer was executed it would imply neglecting important sized locations –those no covered which indeed have a considerable impact for the species and constitute a barrier. For overcoming this obstacle, it was necessary to test a second alternative that made use of the aggregation tool which combines polygons within a specified distance to each other into new polygons. By using this choice was possible to group the buildings for afterwards discarding only these isolated features whose area was less than 1 ha.

Airport

An analysis for figuring out if all the polygons included in the Flugverkehr Landuse (airport data) of ATKIS must be included in the model. For a proper assessment of the information, the data from airport was visualized together with an open street map layer. In this way, it was possible to determine that several areas classified as airport were only meadows for starting airplanes without motor. It is clear that this kind of location does not have an important impact on the wildcat habitat and therefore it is not taken into account as barrier area in the model.

In airport areas there is evident the presence of spaces with no human presence. Therefore, the buffer performed in the model cannot be the same than in the villages' barrier, consistently a buffer of 500 m was applied. Moreover, the literature records several cases of animals that have lived in airports acquainted with relative high disturbance.

Figures 5 a-b Examples of isolated buildings confronted with orthophotos

Roads and trails analysis

Traffic has increased during recent decades and is the main threat for some medium sized carnivores in Central Europe (Van der Zee et al. 1992, Clarke et al. 1998). However, it is not an easy task to make inferences about what is the impact that roads represent for wildcats. The effects of roads on crossing behavior and as physical barriers to carnivores are not clear and may depend on traffic volume as well as design and location of roads (Zimmermann 2004).

Moreover, no all wildcats show the same behavior regarding to traffic: some Individuals limit their daily routine, others stop crossing completely but others continue to cross regularly (Klar et al. 2008).
Carnivores show activity shifts in response to human activity and behavioral responses to vehicle volume (Kolowski, 2007). Despite that roads represent an obstacle for wildcat and they generally avoid areas within 200 m of roads, some of them hunt or rest near roads (Klar et al. 2008, Zimmermann, 2004). Studies show that wildcats are aware of roads as an obstacle, by mean of adjusting the reachable hunting areas or resting places, they are also able to adjust their temporal behavior to traffic volume, and they are alert when crossing roads.

When the traffic volume is considered, the type of road having the major motorways has a more incisive influence. Therefore, an analysis of the roads depending on the traffic volume was taken into account. The categories considered were:

1. Roads with less than 2500 vehicles/day
2. Roads whose traffic is between 2500 vehicles/day and 10000 vehicles/day
3. Roads with more than 10000 vehicles/day

The buffers for the roads followed the values evaluated in the telemetry studies (Klar et al. 2008) The 200 m distance buffer was only applied to the second class roads, for roads belonging to the third category a 300 m buffer was taken into account due to its bigger impact in wildlife; these usually are roads with a high night time traffic volume and might be particularly problematic for the mainly nocturnal wildcats.
Arbitrarily to the roads whose traffic is less than 2500 vehicles/day, no distance buffer was applied; the telemetry studies have determined that these roads do not show an important impact in terms of wildlife disturbance.
Regarding rails literature has no record impact on wildcats; however, because of the noise emitted by trains the buffer value considered in the habitat model is of 100 m as a reminder of the noise produced which can perturb the felid habitat.

3 Analysis of Results

Critical distances from human related structures are highly dependent on the habitat itself and on terrain structure, i.e. the tolerance to human presence is highly related to vegetation cover as well as to forest age and topographic conditions. As some wildcats' observations have shown, sometimes cover vegetation prevails over the human presence and avoidance to human presence is not very strong. In spite of the fact that a distance of 900 m from villages generates a more conservative model, the results provided here are at the same time more realistic when considering the solitary essence of the wildcat.

The total resulting area of suitable habitat in the Baden Württemberg state was about 12300 km2, of which 47 % was located within natural parks. Due to the strategic location in the Black forest region the main parks with a major area of potential habitat are Schwarzwald Mitte/Nord and Südschwarzwald with an area of 1660 km2 and 1980 km2 respectively. A detailed calculation for each natural park can be found in the table 5.

Figure 6 allows the comparison of the suitable habitat areas of natural parks showing for each park the correspondent area classified as suitable habitat. It is remarkable that 74% of Schönbuch park area fits into this classification, only followed by Schwäbisch Fränkischer Wald and Südschwarzwald with 55% and 54% respectively. In this point is important to mention that although the percentage of potential habitat for the Südschwarzwald region is comparably low to its total area, it is the park with the biggest potential habitat area with 1980 km^2.

Natural Park	Park Area (km^2)	Potential Habitat in Parks (km^2)	% Natural Parks in Potential habitat
Neckartal-Odenwald	1284.54	443.16	34.5
Obere Donau	1350.89	488.84	36.19
Schwarzwald Mitte/Nord	3742.58	1659.64	44.34
Schwäbisch-Fränkischer Wald	916.15	501.42	54.73
Schönbuch	155.61	114.4	73.52
Stromberg-Heuchelberg	333.13	157.28	47.21
Südschwarzwald	3699.39	1979.56	53.51
Total	11482.28	5344.31	46.54

Table 5 Ratio of potential habitat to the total parks area

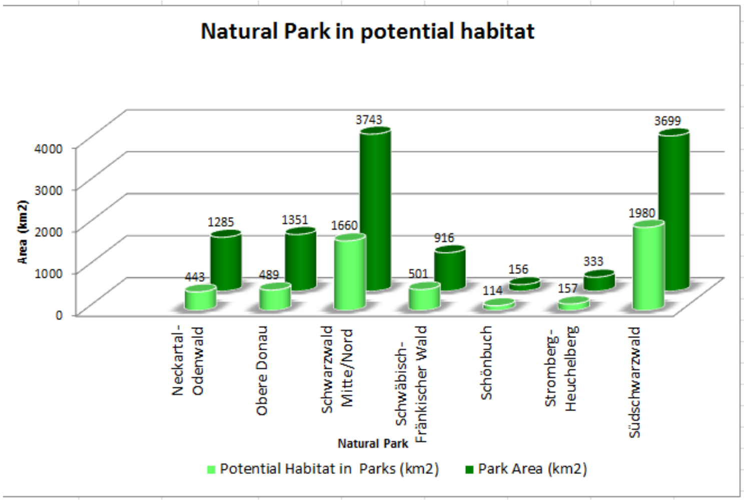

Figure 6 Natural parks area classified as potential habitat for wildcats

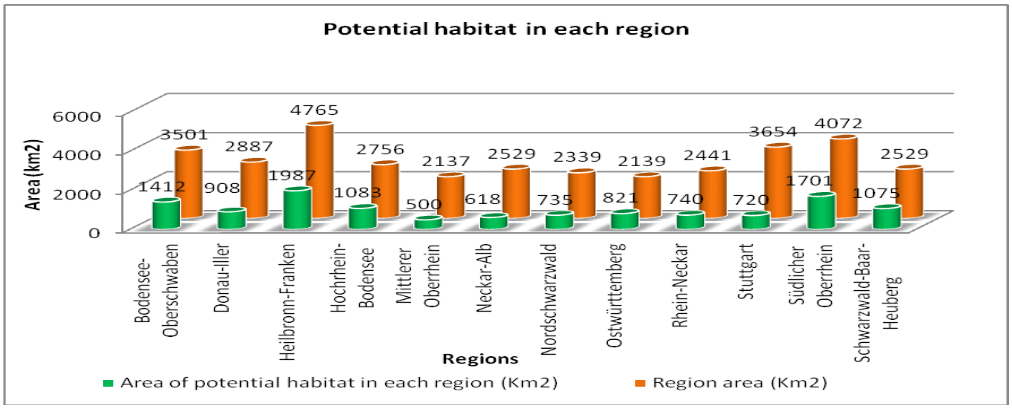

Figure 7 Regions' areas in the state of Baden-Wurttemberg & its suitable habitat for wildcats

The statistics shown in the figure 7 give an idea of how much of the region area was found to be potential habitat. The results from the model performed in this project are encouraging since suitable habitat for wildcats was present in all the regions of BW even in the most and industrialized ones. For instance, in Stuttgart despite of the existing barriers, 20% of the region could be considered suitable. In addition, the biggest region Heilbronn Franken with 4765 km2 has a considerable area included in the potential habitat category which brings about a promising perspective for the conservation of wildcat habitat. Out the total area of the state 12300 km2 approx 35% of the state total area are catalogued as potential habitat. Regions with an important area of suitable habitat are Heilbronn Franken, Bodensee Obershwaben and Südlicher Oberrhein. Conversely, Stuttgart and Mittlerer Oberrhein are regions with little presence of suitable habitat area.

The overview map for the whole state is shown in the figure 8 where in regions like Stuttgart or Mittlerer Oberrhein can be easily recognized lack of suitable wildcat habitat area because of presence of barriers or because of serious water shortage respectively. Figure 8 shows the whole state with its barriers and its potential habitat. The overview of the area illustrates the possibility of suggesting corridors that interconnect suitable patches of habitat e.g. Schwäbisch Fränkischer Wald and Stromberg-Heuchelberg. Additionally, it can be confirmed that in the Black Forest as well as in the Bodensee regions, there is a considerable presence of eligible habitat. Conversely areas highly industrialised have a little representation of suitable habitat.

The result of a suitable habitat model is fragmented areas, which should be connected to get the called corridors. An assessment of these corridors must be done to evaluate which of these connections are feasible. BUND projects agreed to the results given here (Figure 6 almost the whole Schönbuch' area is suitable). The execution of adaption works to accomplish a corridor with stepping stones locations which connect Schönbuch and Gärtringen is being carried out.

3.1 Landuses' Type in Wildcat habitat

Figure 9 shows the distribution of landuses in the potential habitat areas, here can be concluded that forests have the biggest participation in the eligible habitat with 7539.44 km2 representing 62% of the total area followed by special agricultural areas with 35%. The remaining landuse classes are negligible since they only represent 3% of the total area.

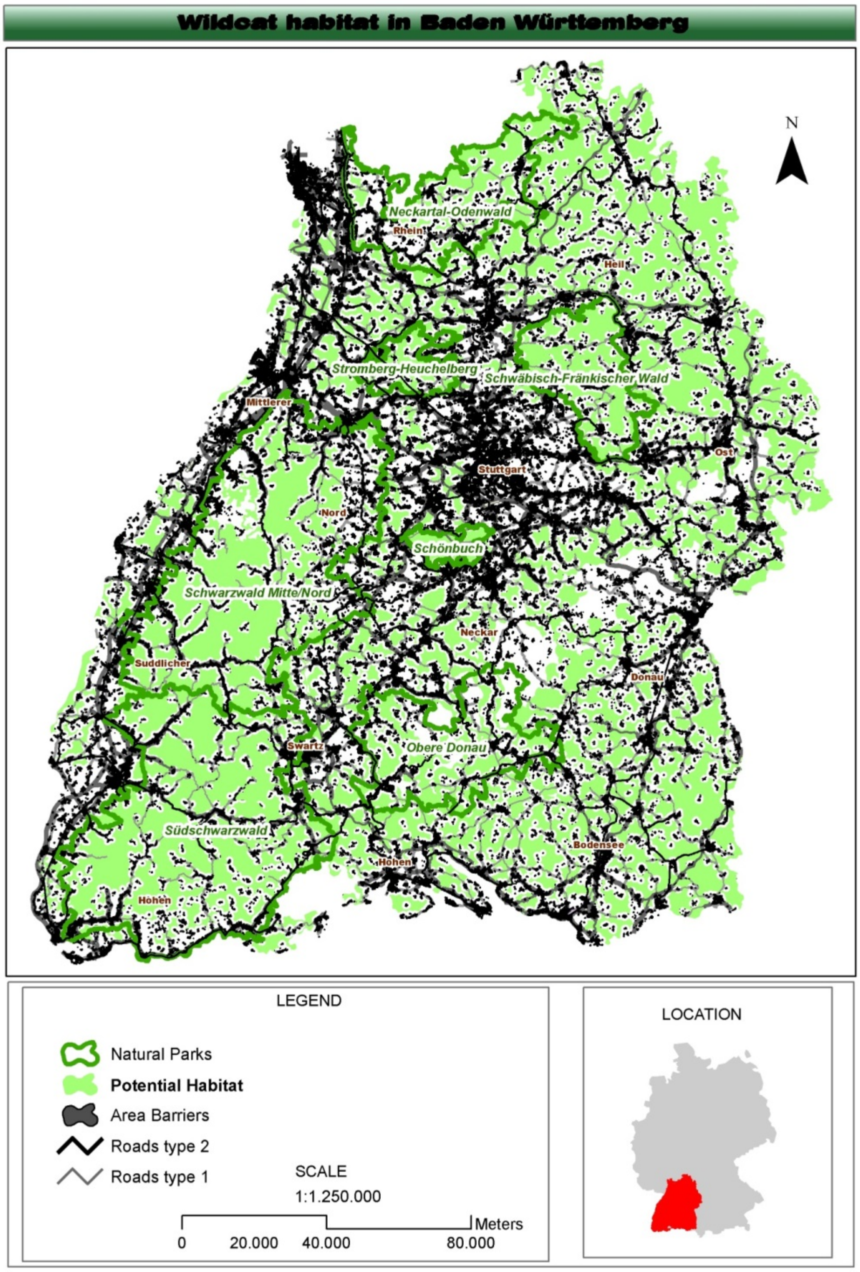

Figure 8 Overview of wild cat habitat in Baden Württemberg. The map includes potential habitat and the total of barriers.

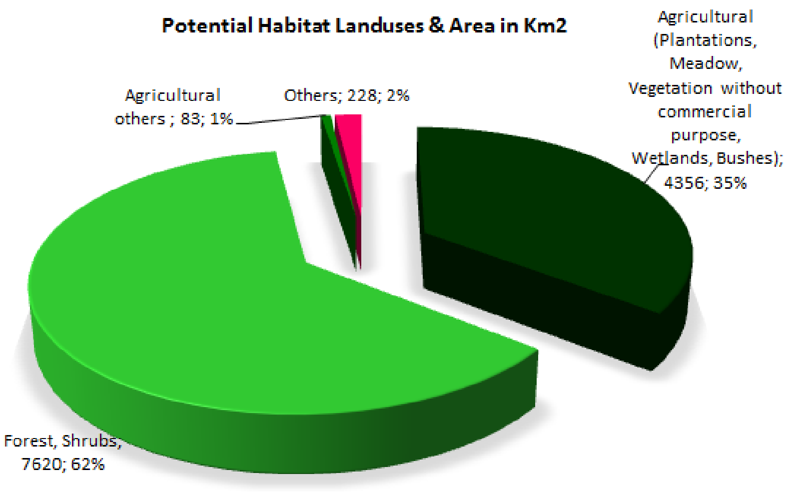

Figure 9 Distribution of landuses in potential habitat

3.2 Validation of the model

Unfortunately, there is neither a wildcat's sample with a proper size nor distribution that fulfils appropriate conditions for validating the model. However, a significant population of the species is located in a small patch in Karlsruhe. Moreover, in the forest between the localities of Unteröwisheim and Oberöwisheim were found new wildcat exemplars (Lechner, 2014). These findings have entirely coincidence with the results yielded by the model.

3.3 Management implications

Although the model given here can be used as base for finding suitable habitat, the use of ground surveys and species occurrences for assessment and validation of the models would be useful. For more detailed models with greater accuracy it is necessary to incorporate field studies and the collection of species occurrence data with an appropriate size and distribution in the whole territory where the predictions are needed.

Additionally, when new datasets are available, this model should be rerun or modified based on that new information. Important to mention is that the habitat model should be considered as hypothesis with iterations that yield more accurate results. As additional knowledge is gained i.e. species occurrence points, wildlife habitat relationship associations, and environmental variables, the model should be rerun.

The model presented here constitutes a base for specific research and monitoring directions for the species, however care must be taken in exact monitoring sites because of the sometimes unpredictable behaviour of animals as well as coarseness of the input datasets among other factors.

The approach developed here which is based on minimal requirements is conservative; therefore, it may have overlooked some areas which could be suitable for wildcats.

Projects about corridors and connection between suitable patches must be studied in a global way since regions with suitable habitats and consequentially corridors go through frontiers. For example, the region of Black Forest is a crucial patch of eligible habitat for wildcats. Because of its size and its convenient conditions for wildlife, this region constitutes an example of areas in which preservation projects must be analyzed and evaluated by German and French planers.

4 Recommendations and Conclusions

The model tackled here is an approach which contains basic requirements for the survival of a wild species. Although the model developed here is only a basis to determine potential locations of wildcats, this approach also constitutes a practical model of easy interpretation whose simplicity is attractive for decision makers. Moreover, models developed with Model Builder give an exceptional opportunity to make the information accessible even to public with no technical knowledge.

Further analysis to refine the model for setting conservation priorities must be addressed. The variables used in a model must be documented to withstand scientific scrutiny, in addition, habitat models are specific for the species and using different approaches may provide a more accurate model for use in planning. The model considered here should be viewed as testable hypotheses and sampling frames for survey efforts. The modeling in this way helps to have in a quick and easy way a glimpse about the habitat of the species.

Furthermore, the approach of modeling based on statistical methods is expensive since surveys are required. These models are based on species occurrence records and use also environmental variables. This process identifies associations through mathematical algorithms and species presence. Traditionally, there has been a need to identify both presence and absence of species for these algorithms to work such as in logistic regression. Recently, several algorithms (e.g.Maximum Entropy; Phillips et al. 2006) have been created that use presence only occurrence datasets for modeling. Despite that statistical approaches are costly, further work with models based on this type of approaches and finer scale environmental datasets would be worthwhile.

It cannot be expected that the resulting location of suitable habitat retrieved in a model is infallible. A model means a simplification of the reality and in this process is quite possible that relevant variables in the suitable habitats of the species are not taken into account. Therefore, no all the variables that affect the species can be modeled. In addition, the behavior from cat to cat might vary very strong individually (Fielding and Haworth, 1995; Zimmermann, 2004).

Special considerations like those about excluding some buildings based on its area because lacking of impact in wildcats habitat can be reformulated when new information about the use of the buildings is collected. Depending on buildings use information, assumptions concerning to human presence and its impact on wildcats could be accounted when modeling.

The modeling approach explained here is not restricted to wildcats and can be extended to other large mammals to restore habitat, improve connectivity, and to develop conservation and management concepts.

Some telemetry observations demonstrate that the capacity to cross barriers may differ considerably between individuals. In species behaviour modelling is about following tendencies and extending them to all species members.

Patch dynamics and populations estimations play a significant role in species persistence. The results from a model provide an input for developing suitable corridors and suggest that the migration between adjacent sub populations is important for the long term stability of the population. The result of the model studied here allows assessing the connections of these patches. In fact a corridor connecting Schönbuch and Gärtringen is being developed. Furthermore, new corridors based on the potential habitat might be proposed and evaluated.

The habitat models are essential for formulating corridors. A map with potential corridors can help to direct decisions on the placement of mitigation measures such as greenbridges or additional habitat structures (Klar et al, 2008) It is important to implement these corridors soon into landscape framework plans to save natural gaps for wildlife between urban and industrial areas before these gaps disappear (Possingham 2000, Grantham et al. 2009).

To obtain a more reliable validation of the model is recommendable to have a significant sized and a wide spread distribution sample as well, located in the whole territory under study.

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Implementation of a MODIS Aerosol Algorithm for Air Pollution Detection

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ABSTRACT

Air pollution has several negative consequences to life. The Continuous Air Monitoring Stations (CAMS) can calculate the levels of this contamination, but their range is too small. An alternative for the detection of the pollution is the use of satellites. The Moderate Resolution Imaging Spectroradiometer (MODIS), instrument on board of the satellite Terra and Aqua from the NASA, allows the calculation of the Aerosol Optical Thickness (degree in which aerosols prevent the transmission of light). The official product has a pixel resolution of 10 km., not good enough for a deeper analysis. A Simplified high resolution MODIS Aerosol Retrieval Algorithm (SARA) is implemented to improve this resolution. The algorithm creates a new raster with a resolution of 500 m. The AERONET data is not used for the calculation; instead, some aerosol models from the software OPAC (Optical Properties of Aerosols and clouds) are used. The algorithm is tested on the region of Bogotá, Colombia. The results are compared to the PM10 observations (Particle matter less than 10 µm/m3) measured by the Bogotá Air Quality Network CAMS showing a correlation of 0.51. Several validations are discussed.

KEYWORDS: Air Pollution, Bogotá, Sara, Modis, Aerosol Optical Thickness, PM10

1 Introduction

1.1 Air Pollution Detection

The industrialization and growing population have a strong impact on environment. It is important to find alternatives to preserve and take care of the natural resources to secure a sustainable development.

One of the big environmental problems is the air pollution. It is considered as the introduction of suspended particles matter in the atmosphere, produced by transportation smoke, dust, soot, fuel combustion, among others. High concentrations of these particles affect human health. The air pollution levels can be estimated using a Continuous Air Monitoring Station (CAMS). The instrument calculates the concentration of suspendend particles matter in the ambient air, usually PM10 (Particle matter less than 10µm/m3). However, they are not useful to interpret the distribution of pollution over big regions like towns or cities. The air contamination can be also detetected using remote sensing devices as MODIS.

1.2 MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is an measuring tool of the National Aeronautics and Space Administration (NASA). It is on board of the satellites Terra and Aqua. The instrument makes registrations of the terrestrial and ocean atmospheric conditions using a high radiometric sensitivity in 36 spectral bands from 0.4 µm to 14.4 µm [1]. The information is available for download using the MODIS Level 1 and Atmosphere Archive and Distribution System (LAADS).

The MODIS records allow the calculation of the *Aerosol Optical Thickness* (AOT), (degree in which aerosols prevent the transmission of light by absorption or scattering of light) [2]. This parameter can be used for the estimation of air pollution, especially when it is used along with CAMS [3]. The official MODIS AOT product has a spatial resolution of 10X10 km at nadir, the size of the resolution can lead to dificulties depending on the studied region. In this research, a method to improve the AOT resolution is implemented. This way, it is possible to make comparisons with ground base monitoring observations.

1.3 Related work

It is shown that it is possible to make a relationship between the particulate matter (PM2.5 and PM10) and the MODIS AOT Data.

Hutchison et. al. made a correlation evaluation using the MODIS AOT (10 km) and PM2.5 observations across Texas [4]. The results show that there is a low correlation (r=0.41) along 3 months, but a stronger one, obtained by averaging the data over one year (r=0.98). However, the use of long periods of time is not suitable for real time observations.

Péré et. al. worked in a mapping of PM10 concentrations derived from MODIS AOT over South – Eastern France [5]. The result shows a strong correlation (r=0.79) for 3 months. It shows better results compared to the PM2.5 correlation from the previous study.

In some studies the AOT parameter is retrieved with a higher resolution. Wanget. al. developed an algorithm to get the AOT at 1 km resolution [6]. It is produced from the MODIS Level 1 data. This product was compared with the PM2.5 observations in Beijing over one month. There is a correlation of r= 0.845 for the AOT at 10km, and a correlation of r = 0.866 for the AOT at 1km, showing a slight advance.

Wong et. al. proposed a methodology for retrieving AOT at 500 m resolution [7]. The results were compared to the AOT data of the ground-based stations in Hong Kong. There is a correlation of 0.877 for the original AOT at 10 km and a correlation of 0.937 for the AOT at 500 m. Nevertheless, the calculation of this process is complex due to the creation of a Lookup table.

A simpler version of the retrieval of AOT at 500 m resolution was created by Bilal et. al. [8]. It was called: *Simplified high resolution MODIS Aerosol Retrieval Algorithm* (SARA). The method does not use a lookup table. Instead, the necessary properties can be obtained from the Aerosol Robotic Network (AERONET), a union of ground monitoring stations established by NASA around the world. The SARA AOT establish a correlation of 0.964 with the ground-based stations. The presented research have its origin in the SARA methodology.

2 Theoretical Background

2.1 Aerosol algorithm

The SARA consists mainly in a set of equations for estimating the Aerosol Optical Thickness from the MODIS instrument. It can be resumed as follows.

The Aerosol Optical Thickness τ_a is described as a function of the aerosol reflectance ρ_{Aer}, cosine of solar zenith angle μ_s, cosine of sensor zenith angle μ_v, Single scattering albedo ω_0 and aerosol scattering phase function P_a (Eq. 1) [9].

$$\tau_{a,\lambda} = \frac{\rho_{Aer(\lambda,\theta_s,\theta_v,\phi)} 4\mu_s\mu_v}{\omega_0 P_{a(\theta_s,\theta_v,\phi)}} \qquad \text{Eq. 1}$$

The aerosol scattering phase function depends on the asymmetry parameter g, and the scattering phase angle Θ (Eq. 2) [10].

$$P_{a(\theta_s,\theta_v,\phi)} = \frac{1-g^2}{[1+g^2-2\,g\cos(\pi-\Theta)]^{3/2}}$$ Eq. 2

The scattering phase angle Θ is a function of the solar zenith angle θ_s, sensor zenith angle θ_v, solar azimuth angle ϕ_s and sensor azimuth angle ϕ_v. The relative azimuth angle described in the formula is $\phi = \phi_s - \phi_v$ (Eq. 3) [11].

$$\Theta = \cos^{-1}(\cos\theta_s\cos\theta_v + \sin\theta_s\sin\theta_v\cos\phi)$$ Eq. 3

The estimation of the aerosol reflectance ρ_{Aer} is longer. This can be done by decomposing the Top of atmosphere reflectance ρ_{TOA} from Rayleigh path reflectance ρ_{RAY} and Surface reflectance ρ_S. The surface reflectance has additional corrections in function of the transmission of the atmosphere on sun-surface path $T_{(\theta_s)}$, transmission of the atmosphere on surface-sensor path $T_{(\theta_v)}$ and the Atmospheric backscattering ratio$S_{(\lambda)}$ (Eq. 4) [7].

$$\rho_{Aer(\lambda,\theta_s,\theta_v,\phi)} = \rho_{TOA(\lambda,\theta_s,\theta_v,\phi)} - \rho_{Ray(\lambda,\theta_s,\theta_v,\phi)} - \frac{T_{(\theta_s)}T_{(\theta_v)}\rho_{s(\lambda,\theta_s,\theta_v,\phi)}}{1-\rho_{s(\lambda,\theta_s,\theta_v,\phi)}S_{(\lambda)}}$$ Eq. 4

The Top of atmosphere reflectance ρ_{TOA} is in function of the Top of atmosphere radiance $L_{TOA(\lambda)}$, the Earth – Sun distance in astronomic units d, the Mean solar exoatmospheric radiation ESUN and the cosine of the sun zenith angle μ_s (Eq. 5). The value of the Mean solar exoatmospheric radiation, depends on the wavelength, its value can be found in [12].

$$\rho_{TOA(\lambda)} = \frac{\pi L_{TOA(\lambda)}d^2}{ESUN_\lambda\mu_s}$$ Eq. 5

The next expression is the Rayleigh path reflectance ρ_{Ray}, this parameter depends on the Rayleigh Optical Thickness τ_R, Rayleigh phase function P_{Ray} and the cosine of solar and sensor zenith view angle $\mu_s\mu_v$ (Eq. 6) [7].

$$\rho_{Ray(\lambda)} = \frac{\pi\,\tau_R P_{Ray}}{\mu_s\mu_v}$$ Eq. 6

The Rayleigh Optical Depth τ_R can be calculated in function of the ambient pressure with respect to elevationP_z and elevation z (Eq. 7) [11].

$$\tau_R = \frac{P_z}{P_0}(0.00864 + 6.5 * 10^{-6} * z)\lambda^{-(3.916+0.074\lambda+0.05/\lambda)}$$ Eq. 7

The ambient pressure respect to elevation can be modeled using the Barometric formula (Eq. 8). Where P_0= Sea level standard atmospheric pressure, M = Molar mass of dry air, gr = Earth – surface gravitational acceleration, R = Universal gas constant, T = Temperature and z= elevation.

$$P_z = P_0 e^{-\frac{M\,gr}{R\,T}z}$$ Eq. 8

The Rayleigh phase function P_{Ray} depends on the scattering phase angle Θ and the depolarization factor $\delta = 0.0279$ for dry air (Eq. 9) [14].

$$P_{Ray(\Theta)} = \frac{3}{16\pi}\frac{2}{2+\delta}\left[(1+\delta)+(1-\delta)\cos^2(\Theta)\right] \quad \text{Eq. 9}$$

The last expression, the surface reflectance is corrected with additional parameters. The transmission of the atmosphere on sun-surface path is (Eq. 10) [8].

$$T_{(\theta_s)} = e^{\frac{-(\tau_R+\tau_a)}{\mu_s}} \quad \text{Eq. 10}$$

The transmission of the atmosphere on surface-sensor path (Eq. 11) [8].

$$T_{(\theta_v)} = e^{\frac{-(\tau_R+\tau_a)}{\mu_v}} \quad \text{Eq. 11}$$

And the atmospheric Backscattering ratio in function of the Asymmetry parameter g, Rayleigh Optical Depth and Aerosol optical Thickness (Eq. 12).

$$S_\lambda = (0.92\tau_R + (1-g)\tau_a)e^{-(\tau_R+\tau_a)} \quad \text{Eq. 12}$$

Recalling the equation 1, all the parameters can be estimated for retrieving the Aerosol Optical Thickness, that remains in function of three unknown variables, single scattering albedo ω_0 , asymmetry parameter g and the Aerosol Optical Thickness itself τ_a (Eq. 13).

$$\tau_{a,\lambda} = \frac{4\mu_s\mu_v}{\omega_0 P_{a(\theta_s,\theta_v,\phi)}}\left[\rho_{TOA(\lambda,\theta_s,\theta_v,\phi)} - \rho_{Ray(\lambda,\theta_s,\theta_v,\phi)} - \frac{e^{\frac{-(\tau_R+\tau_a)}{\mu_s}}\, e^{\frac{-(\tau_R+\tau_a)}{\mu_v}}\, \rho_{s(\lambda,\theta_s,\theta_v,\phi)}}{1-\rho_{s(\lambda,\theta_s,\theta_v,\phi)}\left[0.92\tau_R + (1-g)\tau_{a,\lambda}\right]e^{-(\tau_R+\tau_a)}}\right] \quad \text{Eq.13}$$

2.2 Aerosol models

According to the SARA methodology, the Single scattering albedo ω_0 and the Asymmetry parameter g are estimated from a empirical method using the AERONET AOT data. Nevertheless, due to the lack of AERONET stations, the values are taken from the aerosol models of the software package OPAC (Optical Properties of Aerosols and Clouds).

The 4 aerosol models selected for the investigation are:

- COCL – Continental Clean
- COAV – Continental Average
- COPO – Continental Polluted

- URBA – Urban

3 Implementation

3.1 Case study

The case study is Bogotá, capital city of Colombia, located at the north of South America. The city has an approximate extension of 33 km from south to north and 16 km from west to east, the average altitude is around 2600 meters over the sea, and it has an estimated population of 7,363,782 for 2010. The city; as the principal economic center of the country; has a big industrial and automobile infrastructure that is affecting its air quality.

3.2 Initial Results

The initial results of the implementation are presented in Fig. 1.

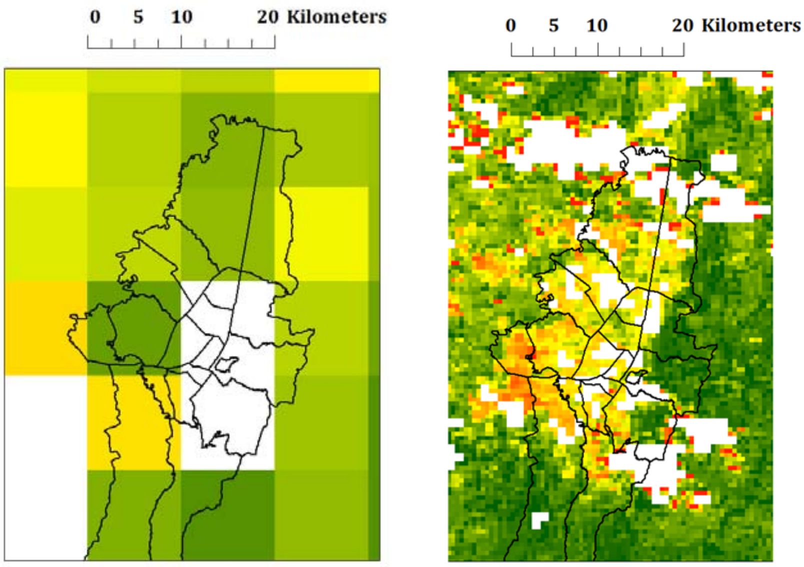

Fig. 1. The first result shows the improvement in the pixel resolution: from 10 km to 500 m. This allows the posibility of making better studies and comparisons to ground monitoring stations.

3.3 Median filter

There were still some corrections to be done. Looking to the clouds (Fig 2. a. left), it is possible to see that the borders have small red pixels, these are part of the clouds that were not excluded using the MODIS cloud mask. In order to remove these outliers, the median filter (Size window 9) is used (Fig. 2).

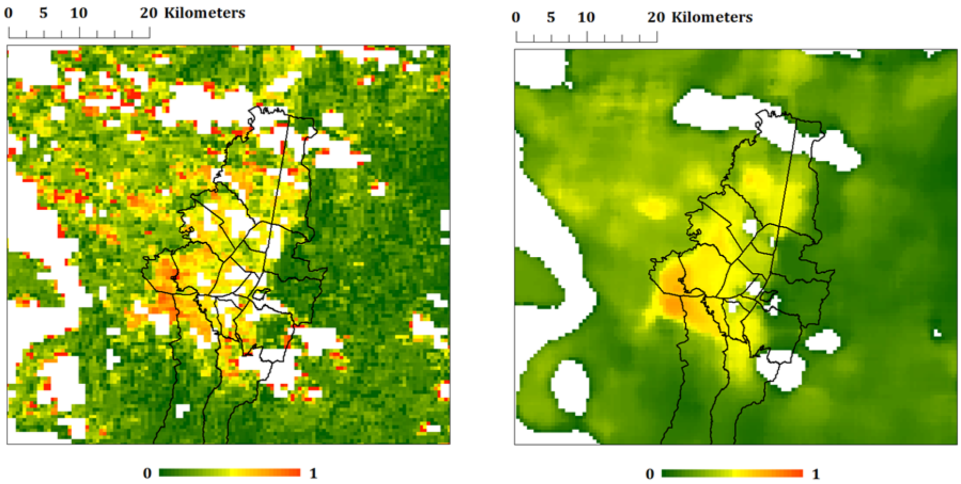

Fig. 2. The median filter removes the outlier values (red pixels) and smooths the image, making easier to visualize the AOT mapping.

4 AOT - PM10 Comparison

4.1 Introduction

The Bogotá Air Quality Monitoring Network observes the air pollution in the city using 14 CAMS (Fig. 3). Each station calculates the hourly PM10 concentration using the BAM 1020 instrument. The PM10 data of 8 months were acquired (Feb. 2013 – Sep. 2013). The data was filtered for making a difference of ±30 min with the satellite overpassing time.

4.2 Limitations

The limitations for the comparison between PM10 and AOT are mainly caused for two reasons: the Terra satellite overpassing position and the cloud covering. The availability of the Terra satellite position reduces the days with registrations from 242 to 139. The cloud covering reduces the PM10 sample data from 1473 samples to just 163 (Table 1).

It is also important to note that the comparison between the PM10 and AOT values is point to point. That means, a value of a ground monitoring station is compared to a AOT value represented in an area of approximate 500 m x 500 m.

	CAMS	Number Samples	Not covered by clouds
1	Usaquen (Bosque)	126	19
2	Sagrado Corazon	136	8
3	Carvajal (Sony)	138	25
4	Tunal	100	2

5	Parque simon Bolivar (IDRD)	114	17
6	Las Ferias (Carrefour)	107	10
7	San Cristobal	109	7
8	Guaymaral (Escuela)	128	16
9	Kennedy	134	21
11	Suba (Corpas)	121	15
13	Puente Aranda	127	17
14	Fontibon	133	6
Total		1473	163
		100%	11%

Table 1. PM10 samples from the Air Quality Monitoring Network.

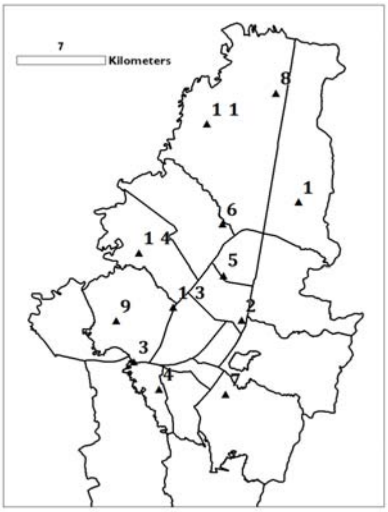

Fig. 3 Distribution of the CAMS in Bogotá

4.3 Correlation

The correlation comparison is presented in table 2. The aerosol model with higher correlation is the Urban one, along with the median filter. the Fig. 4 shows the improvement of using this filter.

	All samples		**95 % Confidence**	
	Number	Correlation	Number	Correlation
URBA	163	0.2093	154	0.1238
URBA – M9	122	0.5004	113	**0.5119**
COCL	163	0.2033	153	0.1286

COCL – M9	122	0.5013	116	0.4690
COAV	163	0.2052	154	0.1185
COAV – M9	122	0.5019	116	0.4676
COPO	163	0.2060	154	0.1196
COPO – M9	122	0.5016	115	0.4895

Table 2 Correlation between AOT and PM10 values (M9 for median filter of window size 9).

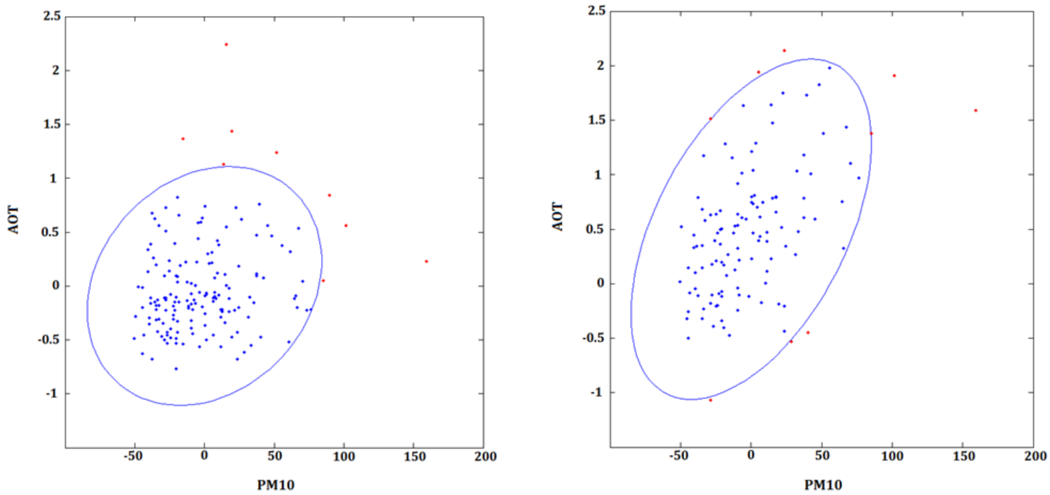

Fig. 4. Correlation between AOT and PM10 with Urban aerosol model for original data (left), median filter (right). The use of the filter creates an improvement from 12.38% to 51.19%. The 95% confidence area is showed inside the blue ellipse.

5 Additional validations

5.1 PM10 Interpolation

Interpolation visualization is one of the procedures for understanding the spread of pollution based on scattering data. It is usually done using the Inverse Distance Weighted method (IDW).

IDW assumes that each measured point gives a local influence that decrease with distance, giving greater weight to locations close to the measured points. The PM10 interpolation is presented in Fig. 5.

According to the figure, harmful concentration of pollution are presented on the west of the city, while a better air quality is shown in the north and south.

The interpolation can approach the visualization of the air quality. Nevertheless, there are some problems related using this technique. First, the method does not consider the effects of the atmospheric conditions.

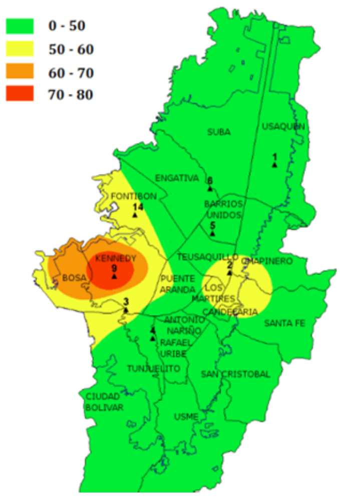

Fig. 5. IDW Interpolation of PM10 data, 27.03.2013.

Second, the number of CAMS is not enough for picture the whole city, especially in the zones far away from the stations. For this reason, a buffer zone of 10 km around the stations was created (Fig. 6. a.).

There are some similarities in the visual representation between AOT and PM10 mapping. The most polluted zones are located in the west. Still, the number of stations is not enough for displaying the data over all the city.

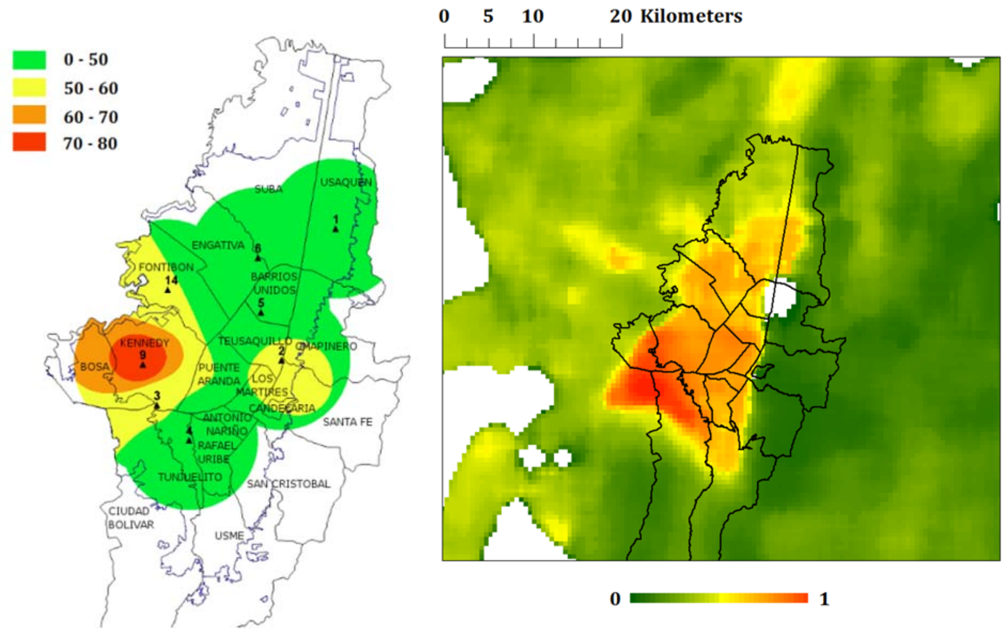

Fig. 6. PM10 Buffer zone interpolation for 27.03.2013 at 15.00 UT (left). The higher levels of PM10 are located in the south-west area of the city; this is equivalent in the AOT map. The AOT results suggest to use CAMS outside the city were predominant levels of AOT are presented.

5.1 Industrial Zones

Bogotá is divided in several locations Fig. 6. a; the locations with more industries are Puente Aranda, Fontibon and Kennedy, in that order [18]; the PM10 and AOT maps from Fig. 6. display high levels in these locations. However, the PM10 map does not include the influence of the surrouding regions of the city, especially from the south-west. A direct comparison of the western industrial center; (highlighted in Fig. 7;) gives a better idea of the behaviour of the air pollution spread. This map suggests the importance of considering the surrounding areas for the study of the air quality.

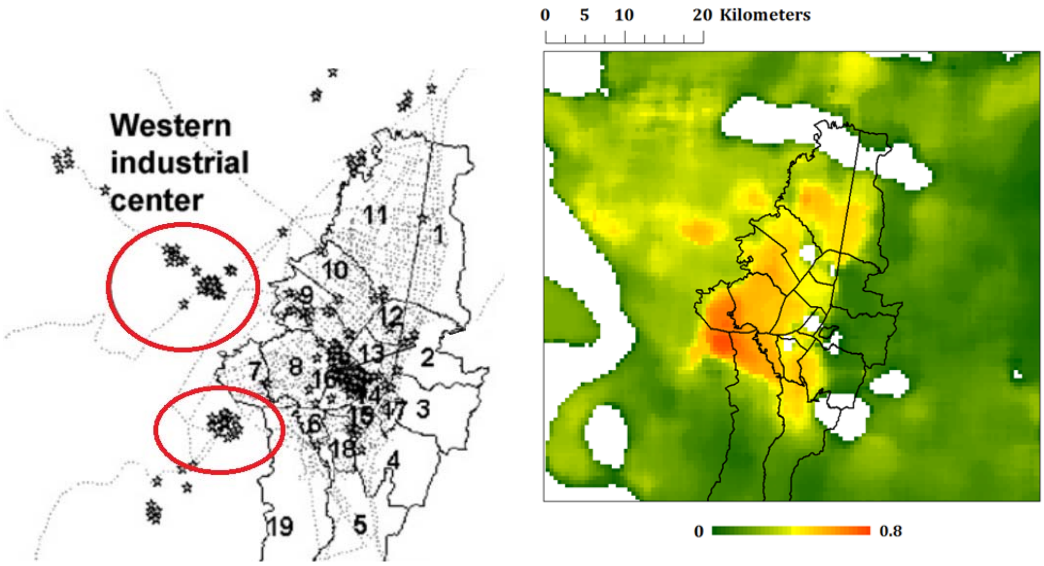

Fig. 7. Western industrial center, taken from **Es ist eine ungültige Quelle angegeben.**. It is clear the equivalence in the AOT map in the regions marked with the ellipses.

5.2 Terrain differences

There are several conditions that influence the distribution of the air pollution from their sources; one of them is the elevation. In the case of Bogotá, the East Mountains stop the propagation of the pollution working as a natural barrier.

To observe this phenomenon, A Digital Terrain Model of 1 km of resolution was created using the Geolocation data from MODIS. The elevation is multiplied 10 times. (Fig. 8). As an additional example, a photo of the city indicates the contrast (Fig. 9). The location of the church (top of the mountain) is presented on the AOT map as a reference. The mountain region is less polluted for several reasons: the presence of forests in the area, the height difference respect to the city, the lack of buildings, industries, highways, among others.

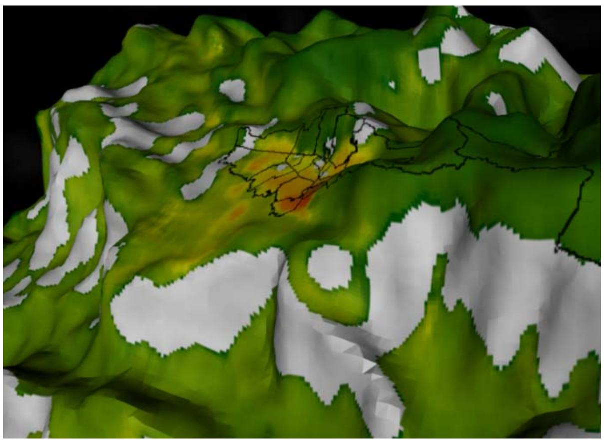

Fig. 8. Digital Terrain Model. The dark green areas in the map correspond to higher elevations or distant places from the pollution.

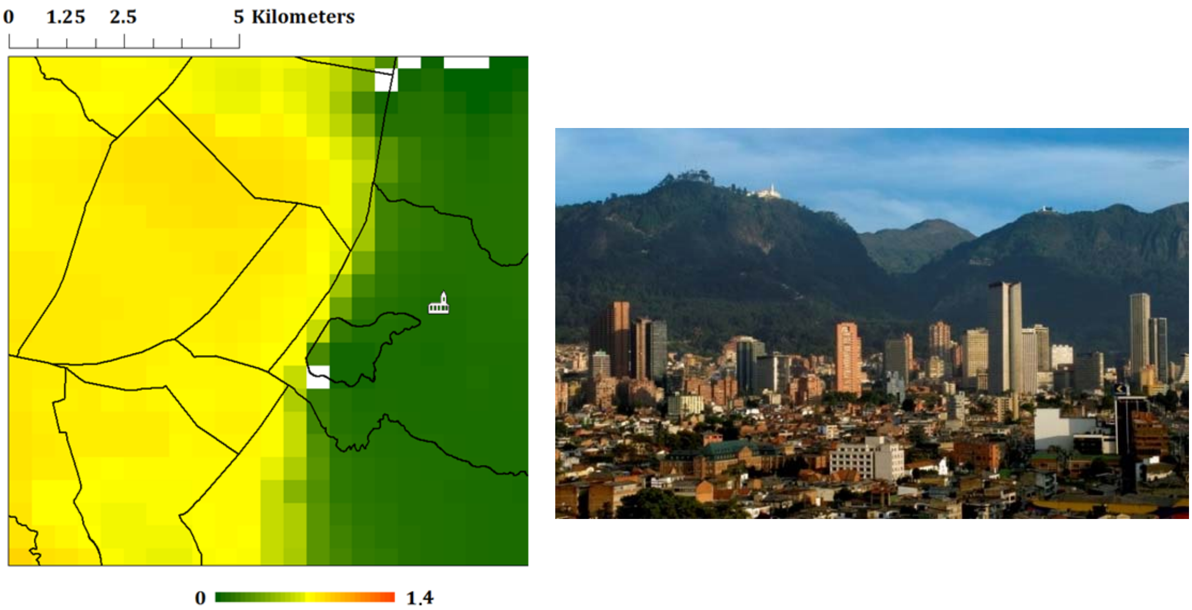

Fig. 9. Bogotá, Colombia. The city is surroundend by mountains in the east, this zone has a very low level of AOT.

6 Conclusion

The implementation of the SARA using aerosol models is an efficient way for detecting the air quality. It can be used for zones that do not have AERONET stations available. The results show a clear distribution of the air pollution, with a correlation of 0.51 between the AOT and the PM10 observations. Furthermore, the precision of the AOT values can be improved using the AERONET data for calibration. This implementation can be used as part of a decision support system, in order to make the quality of the environment better.

Acknowledgment

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