

GNSS Supported Survey and Open Source Web GIS for Forest Inventory and Its Management

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Key words: GNSS, Web GIS, Forest Inventory, GCP, Low Cost Technology

SUMMARY

Demand of cost effective, but precise locational survey in forestry sector is growing as issues relating to Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries have become critical because the land use / land cover changes have significant effect on the amount of greenhouse gas (GHG) emissions. It is also a recognised cause of climate change and global warming. In order to assess the amount of GHG from forestry sector, it is essential to create well defined and easy to maintain forest inventory, preferably online, for wider accessibility and usability. Besides other, forest inventory survey mainly involves mapping of its areal extent and enumeration of predefined parameters of tree and other vegetation for a given area. Mapping is usually done using earth observation remote sensing data while enumeration of tree/other vegetation parameters is conducted by defining sampling plots. Furthermore, being geographical 3D feature, the inventory survey of forest should involve accurate locational as well as height information.

In this study, Global Navigation Satellite System (GNSS) survey technology was applied to create the network of accurate and precise Ground Control Points (GCP). The GCPs were observed using dual frequency GNSS equipment and data was processed by connecting the existing national control points, which resulted into the precise and accurate location and elevation information of the observed GCPs. Sufficient number of well distributed GCPs was observed to create required density of GCPs network so that any inventory sample plot in the study area should fall within 20 km from at least one GCP.

During the forest inventory survey, the nearest GCP point for given inventory sampling plot was identified and used as base station for continuously GNSS observation. Furthermore, inventory sampling plot dimension was measured using GNSS rover. The data was post processed by connecting GNSS base station and rover to obtain precise and accurate 3D locational data of sampling plots. Geographic Information System (GIS) platform enables to integrate the forest inventory plots measurement data with other relevant geospatial data, which resulted into well populated and accurate database. For the user accessibility of the database, an online Web GIS architecture was created using open source software. The low cost technology is easy to handle, manage and maintain up to date database. The database is being used for the forest resource management including GHG emission estimation. The study was carried for the Forestry Commission of Ghana.

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1. INTRODUCTION

In order to harness REDD+ benefit, countries need to estimate GHG emission and establish Reference Levels (RLs) and carbon accounting systems with required standards (Angelsen et al. 2011). Furthermore, while mapping land use/land cover change and enumerating the necessary forest attributes and parameters from the inventory sampling field plots, due consideration need to be given for required spatial and locational accuracy (Bickel et al. 2006) generally defined by the Intergovernmental Panel on Climate Change (IPCC). Locational survey with tradition method is expensive and time consuming, specifically for forestry sector, which are mostly located in inaccessible areas. The handheld GPS (Global Positioning System) can be a quick and cost effective solution, but usually it not meets desirable accuracy. Alternatively differential GNSS (Global Navigation Satellite Systems) gives required accuracy with reasonably quick and cost effective solution, which was employed in this study.

The GNSS started with the launch of the U.S. Department of Defense GPS satellite constellation in the late 1970's followed by Russian GLONASS; the second complete constellation of satellites completed by the end of 2010. Other global and regional satellites constellation is coming in future from European Union, China, India and Japan. Early applications of GNSS were developed mainly for the military and, gradually also used for surveying and mapping and other various fields. A commonly used technique for improving GNSS performance in the field of surveying and mapping is differential GNSS. Using differential GNSS, the position of a fixed GNSS receiver, referred to as a "base station," is determined to a high degree of accuracy using conventional surveying techniques. The base station compares the ranges. Differences between the ranges can be attributed to satellite ephemeris and clock errors, but mostly to errors associated with atmospheric delay. Base stations send these errors to other receivers (rovers), which incorporate the corrections into their position calculations (Weston and Schwieger, 2010). The differential GNSS can be used to locate the position up to few millimeter accuracies (Häkli et al. 2013). Due to this advantage of GNSS, this technique has been widely used to establish control points for high accuracy mapping (Nwilo et al. 2013).

Web mapping has become very popular with increasing demand in the recent years and applied in various sectors including forestry. These web mapping systems revolutionize our industry by allowing anyone with GIS data to quickly publish compelling maps and share those maps online. Much software has come up with their own advantages leading to

competitive production in web mapping field. The specific requirements of the web mapping application are taken into account and development of web mapping application demands careful selection of appropriate software tools (Brown, 2012). Several authors; such as Holmes et al. 2005, Miler et al. 2010; describe the importance of open source methodology for low cost and solution and shown their effectiveness in various field. However, there is not much application in forestry sector, which recently started to attract forestry user as well. In this study a specific approach is described for Open Source GIS with GeoServer, PostgreSQL DBMS, Open Layer and ExtJS to devise web mapping for sharing forest inventory data online.

2. KEY TECHNOLOGIES

2.1 GNSS

GNSS provides autonomous geo-spatial positioning with global coverage. Recently most well-known and most utilized GNSS systems are United States NAVSTAR Global Positioning system (GPS) and Russian GLONASS. For high accuracy position calculation, Differential GNSS (DGNSS) positioning method was used in this study. Differential techniques require access to the observations of at least one reference station with known coordinates. Post processing DGNSS technology has been use to establish GCPs and surveying the location of forest inventory sampling field plots.

2.2 Web GIS

Web GIS involves web resource management and utilization based on internet technology. Web GIS helps to achieve spatial data sharing and interoperability, and it also provides the network service more flexible, intelligent and efficient. Open source database technology “PostgreSQL” has become popular among Open Source users. PostGIS extension enables to store the spatial data on postgresQL database server and also perform spatial operations. Apache HTTP server is used as Web Server for implementation of Web GIS Portal. GeoServer serves as GIS Application Server, which is a full transactional Java (J2EE) implementation of the OpenGIS Consortium's Web Feature Server specification, with an integrated WMS. GeoServer allows the user to share data, process and edit spatial data over the web platform.

3. GNSS SURVEY TO ESTABLISH GCP

3.1 GCP Network Design

A well-structured 59 GCPs network was designed comprising existing 9 national ground control points (GCP); from national Geodetic Reference Network (GRN) control points provided by the Survey and Mapping Division (SMD) of the Lands Commission of Ghana; and 50 newly surveyed GCP in the project area. Considerable lengths of baselines were

chosen to achieve better accuracy. Emphasis was given that at least one GCP should fall within 20km from each of the forest inventory sampling field plots.

The positions of existing 9 and 50 new GCPs were marked on existing topographic map sheets of scale 1: 50,000 covering the project area. The coordinates of the chosen GCPs were determined from the topographic map in Ghana's local system i.e. "War Office". This was then transformed to World Geodetic System (WGS84) UTM zone 30N using Spectrum Survey and Global Mapper software. The coordinates of these GCPs were obtained in both UTM and Geographical Latitude and Longitude format. These coordinates were uploaded in handheld GPS. These navigational GPS used to locate the approximate positions of the points on the ground. Beside the navigational GPS, features such as streams, hills, valleys, tracks and footpaths were other landmarks used to facilitate the identification of the control points, which were extracted from the digital topographic maps.

Most of the ground control points were casted in-situ with concrete monuments of dimension (24cmx24cmx54cm). Out of 54cm height, 24cm were kept above the ground surface and rest 30cm below the ground surface. However some of these monuments were made to be almost level to the ground surface at places where it was likely to be destroyed due to heavy human activities. These points were numbered using the Regional Numbering System specified and provided by the Survey and Mapping Division of the Lands Commission of Ghana. For the forest measurement, Third Order accuracy (FGDC, 1998) was enough, but it was decided that, the accuracy of the control points should be Second Order Class II (FGDC, 1998), so that these control points were used for high accuracy mapping by other agencies. The accuracy of the points were 3cm + 1:20,000.

3.1.1 Hardware and Software used

Following two GPS Hardware and software were used

- i. South S86-S dual frequency static GNSS receiver with $\pm 2.5\text{mm} + 1\text{ppm}$ horizontal accuracy and $\pm 5\text{mm} + 1\text{ppm}$ vertical accuracy and Spectrum Survey Version 4.20 for South S86-S GNSS (for GCP survey)
- ii. Trimble R7 GNSS Receiver with $\pm 5\text{mm} + 0.5\text{ppm}$ horizontal accuracy and $\pm 5\text{mm} + 1\text{ppm}$ vertical accuracy in static mode and $\pm 10\text{mm} + 1\text{ppm}$ horizontal accuracy and $\pm 10\text{mm} + 1\text{ppm}$ in kinematic mode and Trimble Business Center (TBC) Advance for Trimble R7 GNSS (for forest inventory sample plots survey)

3.2 GCPs Data Observations

3.2.1 Observation Planning

Spectrum Survey Planning Module survey planning software tools were used to determine the most appropriate time to collect GPS data. Variety of satellite graphs indicating satellite visibility and geometry were generated and analyzed to determine adequacy of satellite coverage. Figure 1 shows horizontal, vertical and positional dilution of precisions.

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Observations were not taken at times of the day when dilution of precision values were expected less than 3. This was to avoid the introduction of errors and reduction of accuracy in the measurement.

3.2.2 Weather Condition and Elevation Mask

Although weather conditions have no direct influence on data collected during observation, the planning was scheduled such that rainy and stormy conditions were avoided during the observation. Strong windy conditions could affect the stability of the GPS antenna thereby affecting readings being taken during measurement.

The Elevation Mask of 15° was set to get rid of obstacles around the antenna from building, mountains, trees and other features for optimum tracking of satellites. This also filters out signals from satellites below a 15° angle of elevation above the horizon.

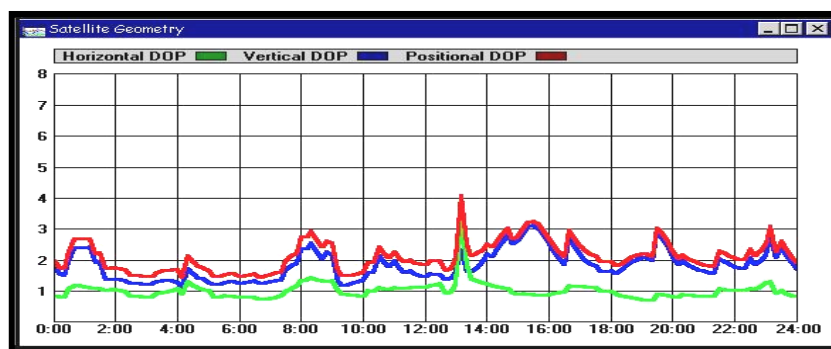


Figure 1: Satellite Geometry Graph (Source: *Spectrum Survey V 4.20*)

3.2.3 Observation Parameters

The following parameters were set and ensured before and during observation to obtain a good quality:

- Geometric Dilution of Precision (GDOP): **Not greater than 4**
- Observation time at a station: **Not less than one hour and thirty minutes**
- Elevation mask set for observation: **+15°**. (This was to model terrain obstruction since points selected were free of buildings, trees and mountains.)
- Minimum log satellites before recording of epochs: **4**
- Troposphere correction: **Measured**
 - Standard model used in South S86-S GNSS and Spectrum Survey Version 4.20
- Ionosphere correction: **On**
 - Dual frequency GPS receivers allow correction of the ionospheric refraction effects, providing results those are practically free from

such effects, for data collected during time period of minimum solar activity. (Paulo de Oliveria et al . 2000)

- Ambiguity resolution: **Search**
- Rejection criteria: **3 x rms.**
 - The RMS error of the new control points were decided as 3cm +1:20000, Second Order Class II (FGDC, 1998). With this rejection criteria, if the calculated accuracy was more than 3 times of RMS, then that calculation was rejected.
- Epoch period: **Begin to End**

3.2.4 Data Observation

The standard static survey method of data capture was used. At a time two existing and three new GCP points were observed using five GNSS equipment. The continuous observation time for data recording was fixed one to two hours depending upon the distance among the five observation points.

3.3 Data Processing

Spectrum Survey Version 4.20 GNSS post-processing software was used to find the unknown coordinates of the survey points by differentially processing data concurrently collected by GNSS receivers. Carrier phase difference techniques were applied to the GNSS observations acquired at different positions.

Differential processing was started by establishing a baseline vector between two survey points on which the GNSS receivers acquired data simultaneously. The software automatically generated these baselines by comparing overlapping epochs from the receiver data collected on each point. One end of the baseline was held as fixed (known Latitude, longitude and Elevation) and relative positioning was used to solve the coordinates for the other end.

3.4 Sample Output Result

Existing base stations (Table 1) from National grid of SMD were used to process the GNSS survey data. The sample output of newly established GCP coordinates are given in Table 2 and all points are plotted in Figure 2. Required accuracy (Table 2) for all established GCPs, in accordance of national standards, has been achieved. Regarding the time and cost, on an average it took half day and 500 US\$ per GCP respectively, for completing all required work of establishing GCPs.

Table 1: Existing Base Station from National Grid of Survey and Mapping Division, Ghana

Point	WGS84 UTM - ZONE 30N			Geographical Coordinates	
BASE STATIONS					
Description	Northing	Easting	Height Ellipsoidal	Latitude	Longitude
	Meter	Meter	Meter	Deg Min Sec (N)	Deg Min Sec (W)
SG GRN 09/NEL1	900041.678	606812.502	139.653	8° 08' 28.51223"	2° 01' 49.58561"
SGB 20/06/GPS 22	811482.453	573131.064	337.607	7° 20' 27.04307"	2° 20' 14.67206"
SG GRN 09/GAS1	752588.560	553491.965	247.191	6° 48' 30.02917"	2° 30' 57.22452"
SG GPS2/08/29C	642583.634	519444.774	119.517	5° 48' 48.34253"	2° 49' 27.68760"
SG GPS2/08/23B	641961.699	563602.435	149.172	5° 48' 27.13548"	2° 25' 31.80482"
SG GPS2/08/32A	713695.596	575854.517	243.751	6° 27' 22.65206"	2° 18' 50.43178"
CFP155	657294.133	818674.482	527.493	5° 56' 20.52922"	0° 07' 19.18065"
SGV 52.07.6	664937.847	899245.029	47.948	6° 00' 13.61859"	0° 36' 18.81192"
SGGA 9787.10.23	641275.941	876828.313	32.581	5° 47' 29.05911"	0° 24' 06.28506"

Table 2: Sample of Newly Established GCP from Fixed Network Calculation

Point	WGS84 UTM - ZONE 30N			Geographical Coordinates		Accuracy	
Description	Northing	Easting	Height Ellipsoidal	Latitude	Longitude	RMS	SD
	Meter	Meter	Meter	Deg Min Sec (N)	Deg Min Sec (W)		
SGB A582.11.FPP01	880225.521	538680.958	390.507	7° 57' 46.85408"	2° 38' 56.48719"	0.015	0.007
SGB A582.11.FPP02	876261.352	567688.548	256.495	7° 55' 36.66988"	2° 23' 09.17585"	0.013	0.009
SGB A582.11.FPP03	862734.597	599017.003	324.600	7° 48' 14.37951"	2° 06' 06.95472"	0.013	0.007
SGB A582.11.FPP04	862257.970	533050.261	349.931	7° 48' 01.90788"	2° 42' 00.83301"	0.016	0.008
SGB A582.11.FPP05	854214.368	553067.574	319.366	7° 43' 39.37937"	2° 31' 07.53254"	0.015	0.007
SGB A582.11.FPP06	839245.108	594624.400	335.594	7° 35' 29.84097"	2° 08' 31.90626"	0.017	0.008
SGB A582.11.FPP07	831318.114	527352.212	304.974	7° 31' 14.49632"	2° 45' 07.46883"	0.02	0.008
SGB A582.11.FPP08	822997.905	546413.539	351.091	7° 26' 43.08382"	2° 34' 45.74654"	0.02	0.008
SGB A582.11.FPP09	816906.166	589618.500	363.758	7° 23' 22.76589"	2° 11' 16.61072"	0.023	0.01

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The RMS error of the control points were decided as 3cm+1:20,000, the RMS error of all calculated points were less than 3cm as shown in Table 2. The standard deviation of the calculated points is less than 0.01, which shows that there are not much variations in RMS errors.

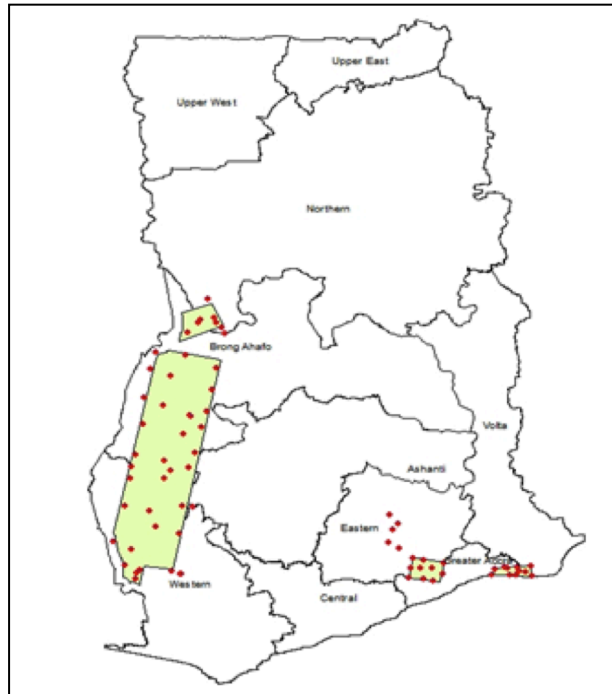


Figure 2: Location of GCPs

4. FOREST INVENTORY SAMPLING PLOT LOCATION SURVEY

Accurate plot location measurement data was required so that forest inventory data could be created from plot enumeration with acceptable accuracy (Gobakken and Næsset, 2008; Gobakken et al. 2013). Furthermore, such accuracy was also needed for various other operation; such as spatial overlay and data extraction, LIDAR (Light Detection and Ranging) assisted modeling for deriving carbon look-up tables including 6 forest carbon pools per broad forest type (strata); to keep the location accuracy and spatial data matching. The 6 forest carbon pools are above-ground (trees), below-ground (root system), deadwood, above-ground non-tree, litter, and soil (up to 30 cm depth).

4.1 Sampling Plot Design

For forest inventory sampling design, LIDAR strips data were used as primary input. The LIDAR strips were flown to capture 3D forest structure after devising the LIDAR sampling scheme using land use map, extracted from satellite imagery, as input (Sah et al. 2012). For sampling plot, the weighted cluster sampling was applied using LIDAR height metrics (85 percentile height) as weights. Each cluster consists of three plots, with the sample plots

distributed within a distance of 500 m of each other balancing between transportation time, overall costs and to avoid spatial autocorrelation effects between plots. The primary cluster reference point is the center point of the most southern plot within a cluster. As listed below, well distributed sampling plots over all dominant ecological zones enable to capture necessary forest attribute data to make it representative forest inventory of Ghanaian forest.

The sample plots were distributed over the ecological zones (Figure 3) as following:

- 1) Savannah, Dry semi-deciduous (fire zone), Dry semi-deciduous (inner zone)
 - total 90 plots
- 2) Moist semi-deciduous zone
 - total 120 plots
- 3) Moist semi-deciduous, Moist evergreen, Wet evergreen
 - total 90 plots
- 4) Upland evergreen
 - total 39 plots
- 5) Southern Margin
 - total 12 plots
- 6) Mangroves
 - total 10 plots

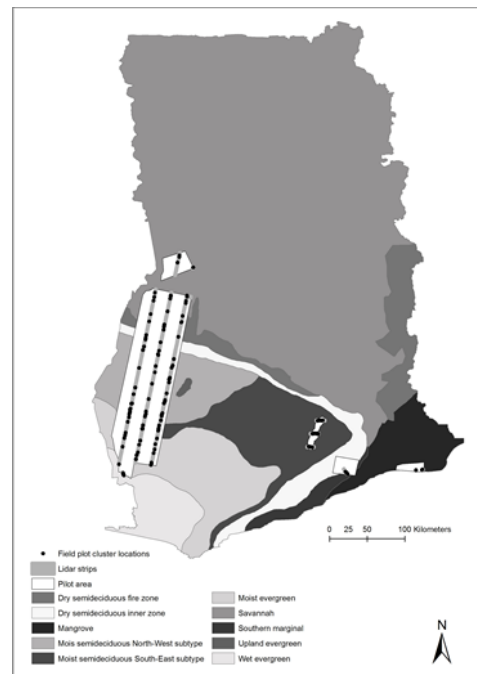


Figure 3: Distribution of Sampling Plots

Quadratic plots equivalent to an area of 400 m² (20 x 20 meters) were used (Figure 4). The primary reference point at center and four corners, in order as shown in Figure 4, define the location of the plots, which were surveyed using GNSS technology as explained earlier. For each plots, forest inventory enumeration was conducted according to the standard practices. Tally and standing dead trees were measured over the entire plot. Juvenile trees and downed deadwood were enumerated from 10 meter times 10 meter subplots. The sub-plot size for seedling measurements was 5 meter times 5 meter. Litter, non-tree and soil samples were collected from two 1-m² subplots located on the south-west – north-east diagonal line, 5 meters apart from the plot center.

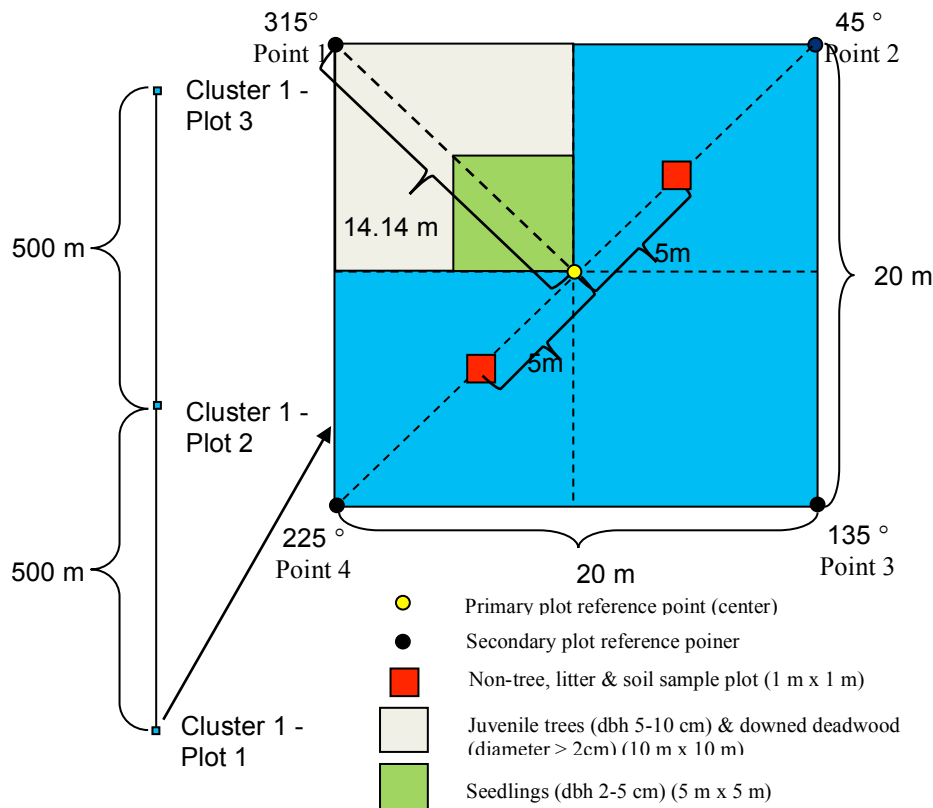


Figure 4: A sample cluster with sub-plots.

4.2 GNSS Measurements

Trimble GNSS hardware and software were used for sampling plot location survey and data processing. One GNSS receiver was setup to the nearby GCP (as base station) point and continuous logging were started for the duration as long as sampling plot was being surveyed of the day. Handheld GPS were used to navigate to the center point of plot. Four corners were laid out with the help of a compass and a tape. The numbering of the points was fixed as shown in the Figure 4. Once all these five points decided, GNSS receiver was set at point 1 recording were started for minimum ten minutes in static mode. Then move to point 2, this process were repeated to all five points in one plot. At some places due to thick vegetation, the satellites were not visible and GNSS were not able to record any data for that point. Efforts were made clearing vegetation above GNSS receiver so that at least one point out of five points from the plot could be observed, so that plot should be mapped in GIS for further analysis. Algorithms were developed to fill the missing points of a plot.

4.3 Plot Location Data Processing

4.3.1 Processing of Captured Data

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Trimble Business Center software was used for data processing. The software provides straight forward procedure, under various options, of data processing captured using Trimble GNSS hardware. In this case post processing DGNSS method was used using data captured from base station and rover GNSS. The accuracy of the processed points were in sub-meter accuracy (Mauro et al. 2011), which is sufficient for forest inventory. The data processing is having following steps in sequence.

- Open a new project
- Import GNSS control (base station GCP) data
- Import GNSS rover data
- Computing coordinate of the points by post processing (Process Base line)
- Report preparation

4.3.2 Computation of Missing Coordinates of Plot

The GNSS survey is done at various kinds of terrain and conditions, such as thickness of forest canopy cover. There were some cases where GNSS observation of all 5 points of plot was not achievable due to lack of satellite signals or poor geometry of satellites over a location due to obstacles (Valbuena et al. 2010). The following approaches were used for computing missing point/s for 3 different encountered cases.

Case 1: Satellite reception was good in all 5 coordinates of a plot

These kind of cases occurred where the canopy cover was medium and also in Savannahs. The GNSS signals were observed properly in all 5 coordinates of a plot. The data was post processed without any missing coordinates. Plot location for sample plot with this kind of case is shown in Figure 5.

Case 2: Satellite reception was difficult in one or few coordinates of a plot.

These kinds of cases occurred where the canopy cover was partially dense. At few coordinates of a plot, the signal reception was good and at some coordinates it was difficult. To compute the plot coordinates in such cases, the other plot coordinates were established by bearing and distance from the measured coordinates by using the expected plot geometry as shown in Figure 3. Various factors affect the estimation of the missing coordinate, such as (i) Number of missing coordinates, (ii) location of point within plot (eg Pt 1 or Pt 2), and (iii) Terrain conditions. Based on these factors various cases were handled. One of such case, which is simpler where single point was missing, is discussed below.

The missing point was estimated with distance of 20m from the adjacent points. Plot location of sample plot with this case has been shown in the Figure 6. Other cases are applied in such way that, if the adjacent coordinates are available then the baseline of known adjacent coordinates are used to estimate with angle of internal polygon angle of 90 degrees and distance of 20m. If the adjacent plot coordinates were not available, then diagonal coordinates

are used to estimate and also with 180 degrees of angle and distance from center point of plot. The magnetic declination at plot center coordinates are taken into account while estimating the bearing of corner coordinates. In case of missing center plot coordinate, then the midpoint of the diagonal coordinates has been used to estimate.

Case3: Satellite reception was very difficult in all coordinates of a plot

Such kind of cases occurred in very dense forests where the canopy was very dense and completely obscures the GNSS satellite signal reception. To compute the plot coordinates, the place nearby plot where canopy cover was less dense had been found out and GNSS location was established with high accuracy. Then the plot coordinates were traversed through bearing and distance measurement from these known coordinates. Also handheld GPS signal was observed at Plot location wherever possible for cross referencing. For estimating the corner of plots, plot geometry had been used as shown in Figure 4. The magnetic declination at plot center coordinate had been taken into account while estimating the bearing of corner coordinates. Plot location of sample plot with this case is shown in Figure 7.

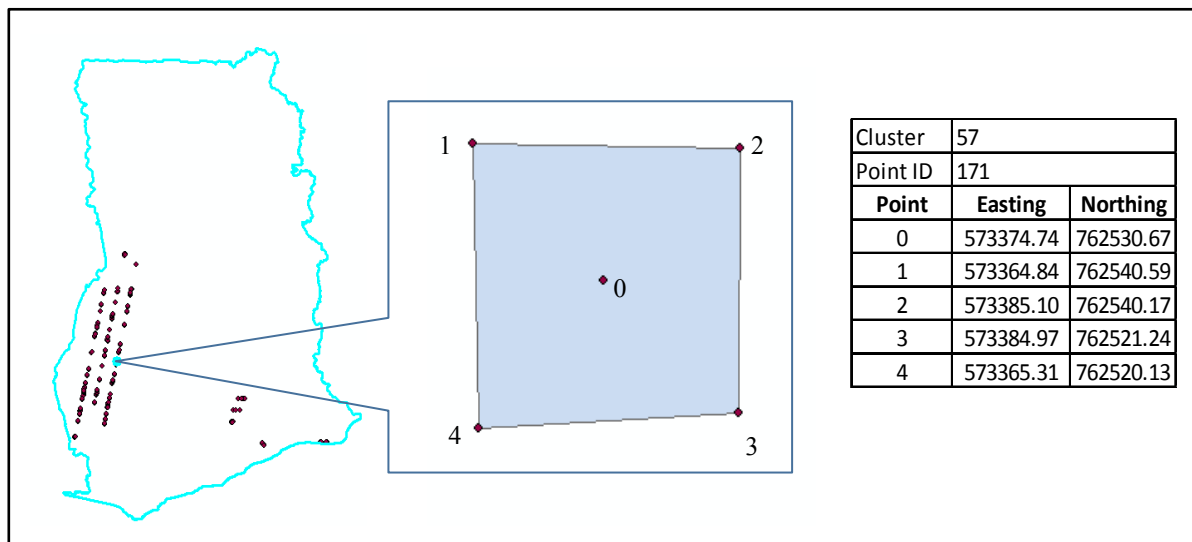


Figure 5: Sample Plot Location with Case 1

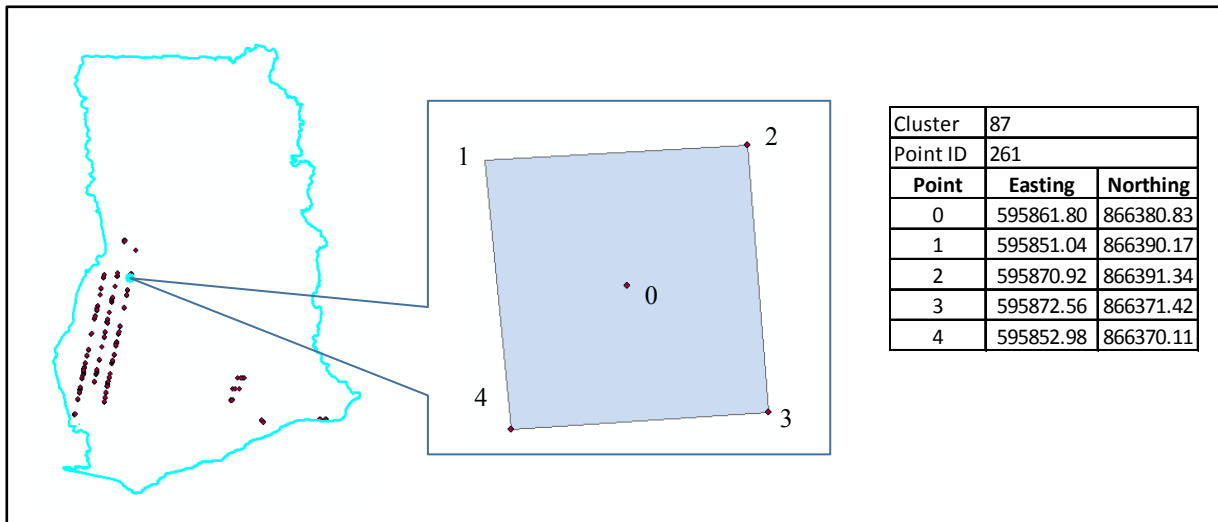


Figure 6: Sample Plot Location with Case2

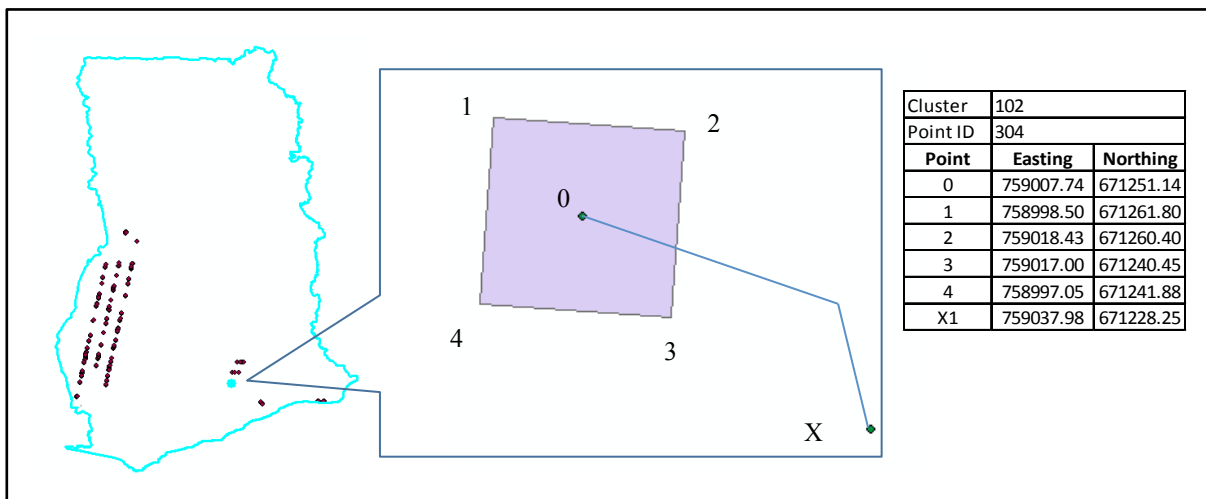


Figure 7: Sample Plot Location with Case3

5. WEB GIS PORTAL

5.1 Web GIS Architecture

The Web GIS architecture used for Forestry inventory GIS web portal is 3-layer architecture which is shown in Figure 8.

5.1.1 Presentation/User Layer

The Presentation layer deals with different views which are accessed by users. These include i) General public view, where the portal is restricted access to public ii) Custom User view,

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which is for Users of Forestry Commission (FC). The application works in a role based model. In this model there is authentication mechanism, where the data and views are customised according to the user access permissions. FC system administrators control the users and their permissions. GIS administrator can restrict permission to user on specific vector or raster data for viewing or editing. This facilitates end user with customised views and data access to avoid conflicts and confusions with other users and data.

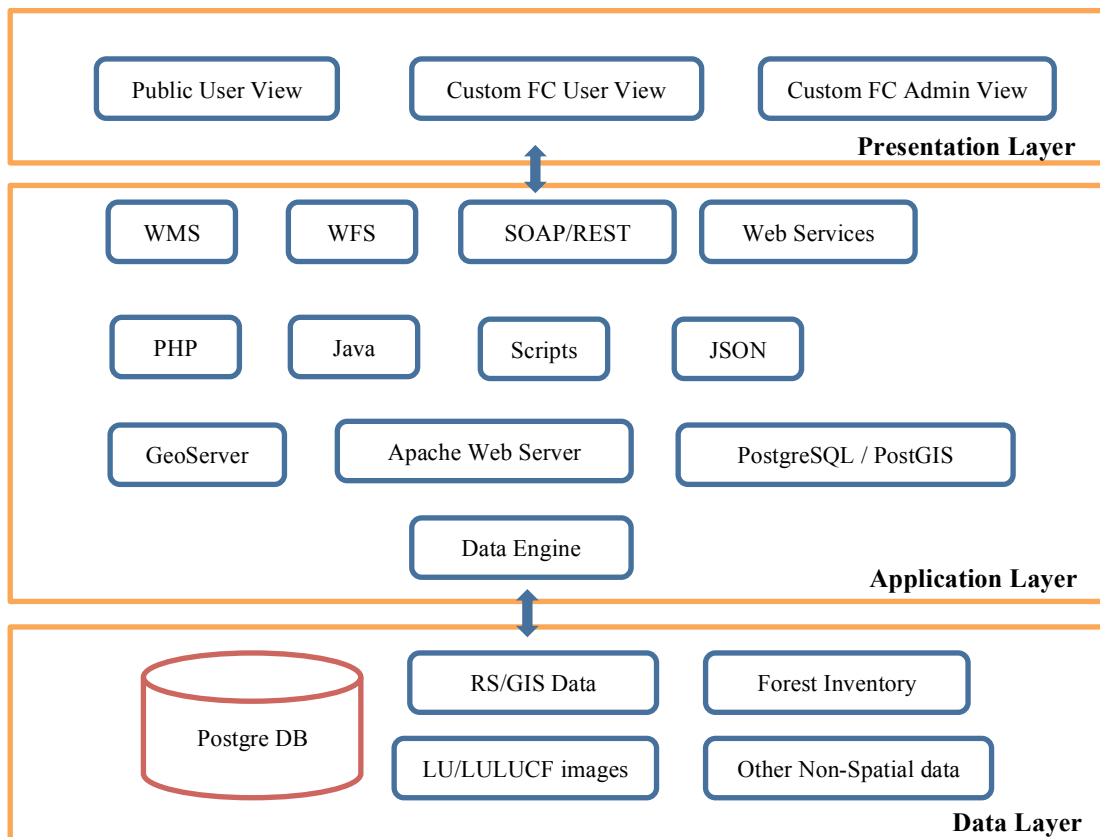


Figure 8: Three Layer Architecture of Web GIS Portal

5.1.2 Application Layer

Application layer is core part of this web architecture. The main functions of the application layer are i) Business Logics: All business logics are implemented in this layer. Various types of processing are done by different set of software and programming languages. It also coordinates the different process to achieve desired business logic. ii) Server Components: This forms base for hosting the application. These include the a) Apache Web Server, which is responsible for hosting the web sites b) GeoServer, which acts as GIS Server responsible for hosting GIS Services like WMS, WFS, etc. and c) Postgre SQL Server handles all the

database operations. The business logics for this web portal are implemented in PHP, Java script, ExtJS, Openlayers and GeoExt.

5.1.3 Data Layer

Data layer contains the underlying database which is both spatial and non-spatial. Spatial data includes GIS, remote sensing data and Forest inventory data. GIS data includes vector data like Forest reserves, Soil classification, Transportation network, settlement locations, ecological zones, Socio economic data, etc. It also includes Remote sensing data like land use classification for different epochs (1990, 2000, 2010), land use change for forestry for different set of epochs (1990-2000, 1990-2010, 2000-2010). Forest inventory data includes biomass/carbon for 6 different pools like above ground, below ground, etc. Data layer also includes other detailed Forest inventory data which were collected from field plots.

5.2 Application of Web GIS in Ghana Forestry Commission

Forestry commission of Ghana has implemented WebGIS portal under the Forest Preservation Programme (FPP). Resource Management System Centre (RMSC), located at Kumasi, part of Forestry Commission responsible for GIS and Remote Sensing, has been hosting the main Database/GIS, which have all the GIS data, Remote sensing data, Forest Inventory data and other spatial database. The Web server, which has the spatial data, is serving to the public for data sharing and also restricted FC user access for protected contents. It also hosts the website for FPP related activities. The Backup Server is being hosted at Forestry commission headquarters which is replica of the Database/GIS server at RMSC. The RMSC servers and FC Headquarters servers are connected through the high speed VPN connection.

Web GIS is now an effective data sharing, which could create environment awareness. For example Land use map of 3 epochs 1990, 2000, 2010 derived from satellite images and used for change detection could be accessed for data roaming to understand how forest cover is changing over time in Ghana.

As mentioned earlier, forest attributes data were collected as pre planned and carefully selected plots to estimate the biomass/carbon stock of 6 different pools. LIDAR scanning was also done covering different ecological zones. Satellite images, LIDAR and Field collected data were used to estimate the biomass/carbon stock by devising appropriate allometric models. These various data has been stored in PostgreSQL database along with developed model and devised biomass/carbon stock estimation software tools in the central database server. Overall system architecture for Ghana FPP programme is mentioned in figure 9. The data flow for the Web server is shown in Figure 10. Web Server hosts the website on Apache HTTP Web Server.

The data flow starts with the user entering the web address on the browser then, i) the Apache HTTP Server asks for user authentication (Optional for certain pages only or else skips to step 4: figure 10), ii) User enters the credentials and then the server verifies it, iii) Page requests

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maps from GeoServer and internally prepares the map for display from GIS Data hosted on GeoServer, and finally iv) Forest inventory software displays the map to user on the web browser.

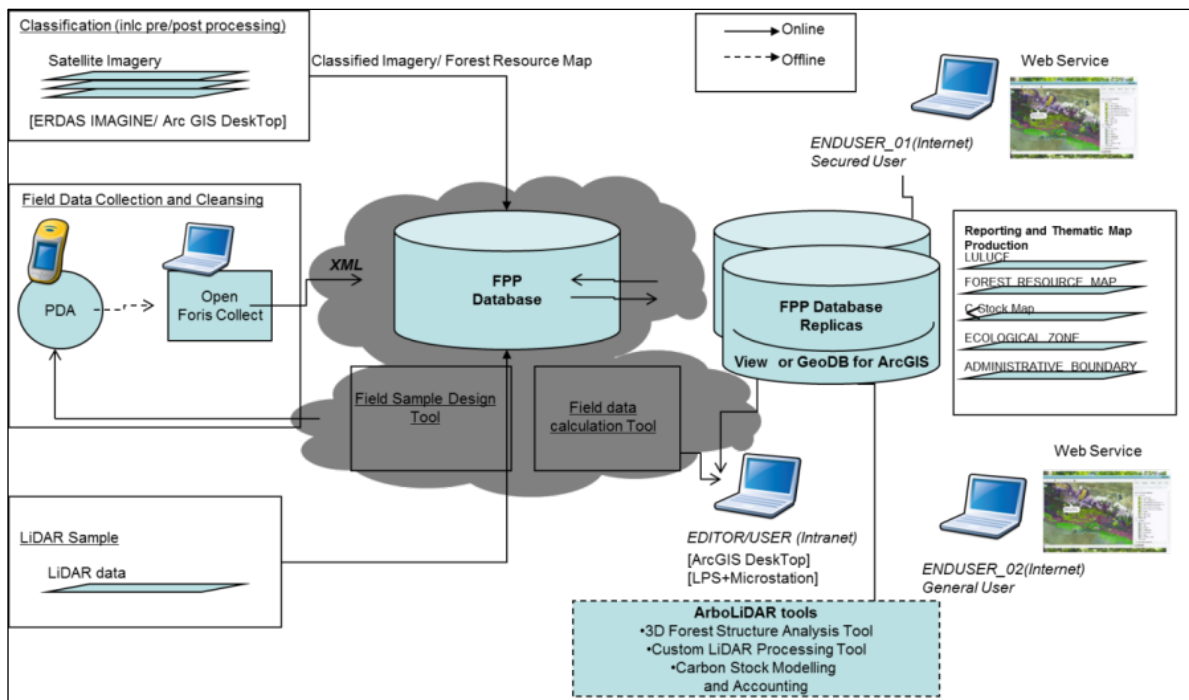


Figure 9: FPP System Architecture

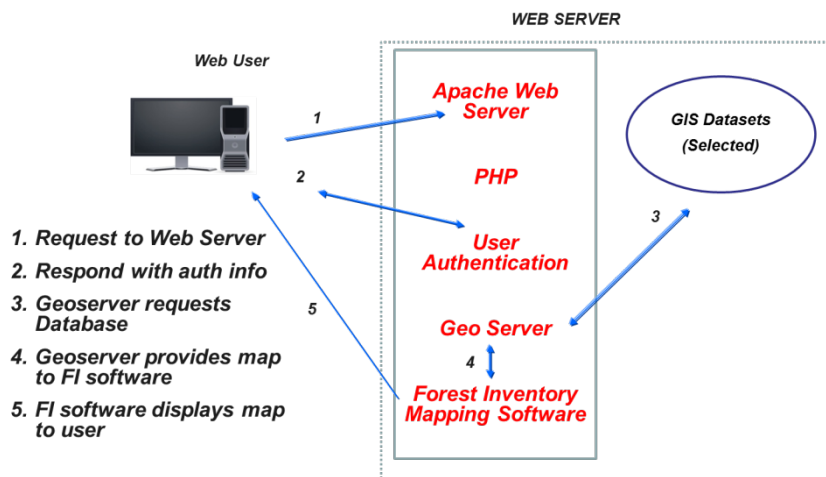


Figure 10: Web Server data flow

6 CONCLUSION

6.1 GNSS

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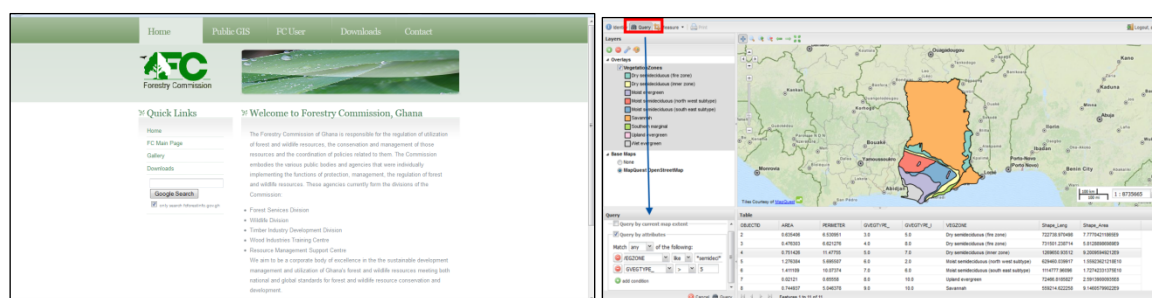
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It has been observed that DGNSS is accurate and less time and resource consuming method of establishment of GCP for forest inventory survey work. As GNSS height measurement was processed in ellipsoidal height, thus the ellipsoidal height was used for all other data processing in this study, such as LIDAR data acquisition and processing and GNSS survey for forest inventory sampling field plots. It is recommended that Survey and Mapping Division of Ghana, should devise an accurate Geoid model of the country, so that GNSS and LIDAR data can be transferred to the Orthometric height for other engineering applications.

6.2 GIS Web Portal

WebGIS portal with 3 tier architecture discussed has been deployed successfully at Ghana Forestry Commission ICT department. GeoServer has been used as Web GIS Server, which serves all vector and raster data. The customised Web GIS portal was developed using Openlayers, OpenGeoSuite SDK suite components and ExtJS technology.

System was customised according to role based user access. Web GIS portal for public will help to browse, pan and explore various available GIS layers. FC Users can access some restricted data, which are authenticated by FC admin with appropriate credentials. Screenshots of Web GIS are shown in figure 11. WebGIS portal and GIS based analysis capabilities are useful assets for FC to protect environment and their forest reserves in better way. Also it can be used for estimating the carbon stock at regular intervals in future.



a. Ghana FPP Homepage

b. Web GIS page

Figure 11: Screenshots of Web GIS

REFERENCES

1. Angelsen, A., Boucher, D., Brown, S., Merckx, V., Streck, C., and Zarin, D., 2011, Guidelines for REDD+ Reference Levels: Principles and Recommendations. Report Prepared for the Government of Norway, Meridian Institute, Washington DC, USA. <http://www.REDD-OAR.org> (visited on 13 Sep. 2013).
2. Bickel, K., Richards, G., Kohl, M., Rodrigues, R. L. V., and Stahl, G., 2006, IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry

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and Other Land Use “Consistent Representation of Lands”, Kanagawa, Japan http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/ (visited on 13 Sep. 2013)

3. Brown, C., 2012, Online GIS – Meet the cloud publication platforms that will revolutionize our industry, <http://www.onlinegis.com> (visited on 15 April 2012)
4. FGDC-STD, 1998, Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks, <http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part2/chapter2> (visited on 11 September 2013)
5. Gobakken, T. and Næsset, E., 2008, Assessing effects of sample plot positioning errors on biophysical stand properties derived from airborne laser scanner data, *SilviLaser 2008*, Sept. 17-19, 2008 – Edinburgh, UK, 14-21 p.
6. Gobakken, T., Korhonen, L., Næsset, E., 2013. Laser-assisted selection of field plots for an area-based forest inventory. *Silva Fennica* vol. 47 no. 5 article id 943. 20 p.
7. Häkli, P., Kallo, U., and Puuponen, J., 2013, From Passive to Active Control Point Networks – Evaluation of Accuracy in Static GPS Surveying, FIG Working Week 2013, Environment for Sustainability, Abuja, Nigeria, 6 – 10 May 2013
8. Holmes, C., Doyle A., and Wilson, M., 2005, Towards a Free and Open Source (FOSS) Spatial Data Infrastructure From Pharaohs to Geoinformatics, FIG Working Week 2005 and GSDI-8, Cairo, Egypt April 16-21, 2005
9. Mauro, F., Valbuena, R., Manzanera, J.A., and Garcí’a-Abril, A., 2011, Influence of Global Navigation Satellite System errors in positioning inventory plots for tree height distribution studies, *Canadian Journal for Forest Research*, 41, 11–23 (2011), <http://www.nrcresearchpress.com/doi/full/10.1139/X10-164>, (visited on 22 Oct, 2013)
10. Miler, M., Odobasic, D., and Medak, D., 2010, FIG Working week 2010, Facing the Challenges – Building the Capacity, Sydney, Australia, 11-16 April 2010
11. Nwilo, P., Odegbare, D., Adegboye, B., and Ibrahim, G., 2013, Comparison of the Processing of GNSS Data using Fixed Ground Stations (Triangulation Stations) and the NIGNET: A Case Study of the South-South Zone of Nigeria, FIG Working Week 2013, Environment for Sustainability, Abuja, Nigeria, 6 – 10 May 2013
12. Paulo de Oliveria, C., Joao Francisco, G. M., Luiz Danilo, D. F., 2000, Application of ionospheric corrections in the equatorial region for L1 GPS users, *Earth Planets Space*, **52**, p1083–1089
13. Sah, B. P., Hämäläinen, J., Sah, A. K., Honji K., Foli, E. G. and Awudi, C., 2012, The Use of Satellite Imagery to Guide Field Plot Sampling Scheme for Biomass Estimation in Ghanaian Forest, *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume I-4, pp 221 to 226.
14. Valbuena, R., Mauro, F., Rodriguez-Solano, R., and Manzanera, J. A., 2010, Accuracy and precision of GPS receivers under forest canopies in a mountainous environment, *Spanish Journal of Agricultural Research* 2010 8(4), 1047-1057, <http://revistas.inia.es/index.php/sjar/article/view/1242/1336> (visited on 12 May 2013)
15. Weston, N. D., and Schwieger, V., 2010, Cost Effective GNSS Positioning Techniques, FIG Publication No. 49, FIG Commission 5 Publication

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