ISO19152 Land Administration Domain Model-oriented Niger River 3D Satellite Mapping

- Osaka Metropolitan University: Erdoo Paula Awai, Nigeria
- Osaka Metropolitan University: Ramata Coulibaly; Bamako, Mali
- GeoNet, Inc. CEO: Hiroyuki Hasegawa; Osaka Pref., Japan
- University of Fukui Professor: Toshihiro Tsukihara; Fukui Pref., Japan
- Bank of Ghana: Doe Rosemary Elikem; Accra, Ghana

Key words:
ISO19152-Land Administration Domain Model, UTM map projection,
Differential GPS 3D mapping, Satellite photogrammetry 3D mapping,
4D Image Map Archive Designed Aerial Studies (IMADAS)

Summary

This presentation will introduce the system configuration, survey map production regulations, and map creator training process for creating 3D cadastral maps in the Federal Republic of Nigeria and the Republic of Mali along Niger river in accordance with ISO19152-LADM (Land Administration Domain Model), based on the current state of cutting-edge fields in Japan and around the world.

According to the Land Survey Act and the Cadastral Survey Work Regulations, to create cadastral maps, the reference control point can be determined as the Japan basic triangulation point (electronic control point) of GNSS satellite surveying and the instrument point and backsight point of a total station surveying system that performs ground (one parcel)surveying from that alone, which is called the Japan single-point observation method, officially.

Osaka, a pioneer in cadastral surveying in Japan, completed 1/ 20,000 topographical map in 1910 (Meiji 43), and since 1952 has been able to display, measure, and store nationwide data for each paddy field plot using a unified coordinate system on a GIS system(UTM map projection). The creation of cadastral maps began with the Johri land administration system of the Taika Reforms in 645 A.D., and continued through Toyotomi Hideyoshi's "Taiko Land Survey" and “Shogun” Tokugawa Ieyasu's "National Map Creation," which crushed the Pope and the King of Spain's plans to occupy Japan and enslave the Japanese in the 1590s by expelling them and the Christians with the world's largest gun army,

before leading to the land tax reform and cadastral map creation of the 1870s .

We propose, with the world-leading satellite surveying and photogrammetry, the followings；

(1) WGS84-UTM Zone -1/10,000 National Land Base Map Boundary Setting Method
(2) DGPS Satellite Surveying - Large-Scale 3D Cadastral Mapping
(3) Existing Aerial Photographs - Bundle Aerial Triangulation - 3D Topographic Mapping
(4) High-Resolution Satellite Image Photogrammetry 3D Mapping

ISO19152 Land Administration Domain Model⁻oriented Niger River 3D Satellite Mapping

－ **Osaka Metropolitan University: Erdoo Paula Awai, Nigeria**

- Osaka Metropolitan University: Ramata Coulibaly; Bamako, Mali

－ **GeoNet, Inc. CEO: Hiroyuki Hasegawa; Osaka Pref., Japan**

－ **University of Fukui Professor: Toshihiro Tsukihara; Fukui Pref., Japan**

－ **Bank of Ghana: Doe Rosemary Elikem; Accra, Ghana**

Introduction

This presentation will introduce the system configuration, survey map production regulations, and map creator training process for creating 3D cadastral maps in the Republic of Ghana and the Republic of Mali in accordance with ISO19152-LADM (Land Administration Domain Model), based on the current state of cutting-edge fields in Japan and around the world.

According to the Land Survey Act and the Cadastral Survey Work Regulations, to create cadastral maps, the reference control point can be determined as the Japan basic triangulation point (electronic control point) of GNSS satellite surveying and the instrument point and backsight point of a total station surveying system that performs ground (one parcel)surveying from that alone, which is called the Japan single-point observation method, officially.

Osaka, a pioneer in cadastral surveying in Japan, completed 1/ 20,000 topographical map in 1910 (Meiji 43), and since 1952 has been able to display, measure, and store nationwide data for each paddy field plot using a unified coordinate system on a GIS system (UTM map projection). The creation of cadastral maps began with the Johri land administration system of the Taika Reforms in 645 A.D., and continued through Toyotomi Hideyoshi's "Taiko Land Survey" and “Shogun” Tokugawa Ieyasu's "National Map Creation," which crushed the Pope and the King of Spain's plans to occupy Japan and enslave the Japanese in the 1590s by expelling them and the Christians with the world's largest gun army, before leading to the land tax reform and cadastral map creation of the 1870s .

We propose, with the world-leading satellite surveying and photogrammetry, the following:

(1) WGS84-UTM Zone -1/10,000 National Land Base Map Boundary Setting Method

(2) DGPS Satellite Surveying - Large-Scale 3D Cadastral Mapping

(3) Existing Aerial Photographs - Bundle Aerial Triangulation - 3D Topographic Mapping

(4) High-Resolution Satellite Image Photogrammetry 3D Mapping

Chapter 1. WGS84-UTM Zone -1/10,000 National Land Base Map Grids Setting

Map projection and CAD globe that overcome cartography colonialism and the data copyright issues of Google Earth: with the invention of CAD globe, we propose a map projection method for creating basic national maps as a WGS84-based ellipsoid-UTM zone version, supported by GNSS satellites geodetic network adjustments, satellite image photogrammetry, bundle triangulation, and digital stereo plotter (AutoCAD version), which are the basis of ISO19152-Land Administration Domain Model as global standard. UTM map projection was originated from Gauss-Krueger conformal transverse cylindrical map projection and named after the book “Handbuch der Vermessungskunde, 1948”.

Cartography played a significant role in colonialism, functioning as a tool for claiming territory, imposing political control, and shaping public perception by framing colonized lands as empty or "discoverable" by European powers. Colonial maps served to dispossess Indigenous peoples, divide communities, overwrite local histories and languages with colonial ones, and establish artificial boundaries that continue to cause conflict in postcolonial nations. These maps were not neutral but were powerful mechanisms of domination that encoded power relations and served the interests of colonial empires. Cartography colonialism is thus criticized, as is the execrable political buzzword "labouring poor," which symbolizes the primitive accumulation of the capital accumulation process that is the essence of colonialism. In authentic 3D-DX (Digital Transformation initiative) cartography, economic entities are represented alongside 3D topography, to ensure Land Administration Property and Sovereignty.

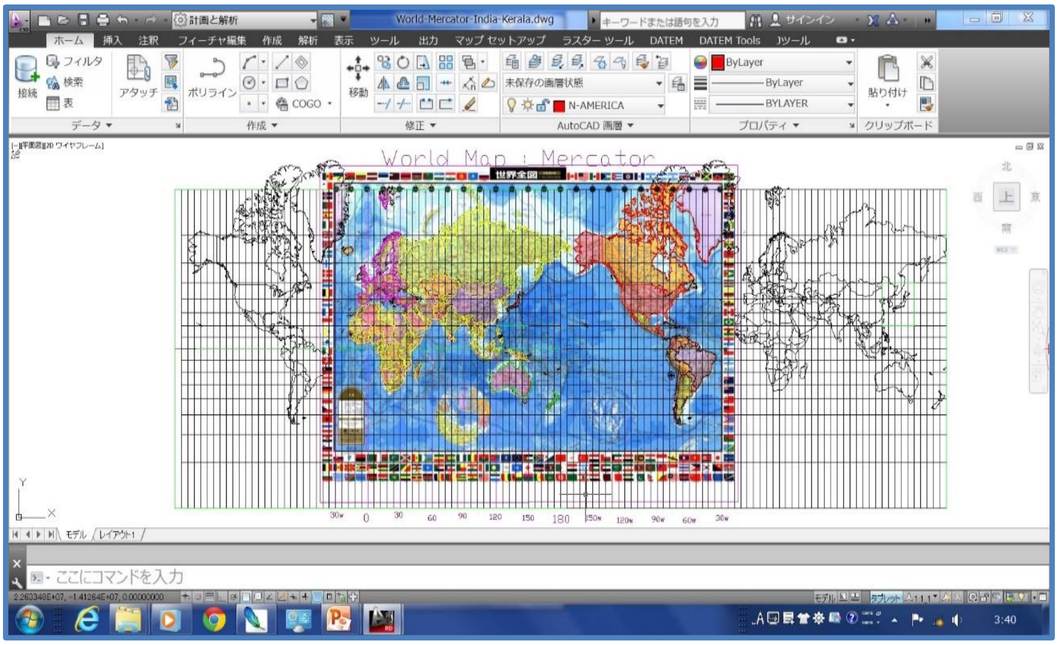


Fig. 1.01 Cartography Colonialism : World Map Mercator map projection

AutoCAD map image before CAD-Globe - 1992

CAD Globe was defined by Hiroyuki Hasegawa in 1992, at presentation in the International Society of Photogrammetry and Remote Sensing; ISPRS 1992 Washington congress.

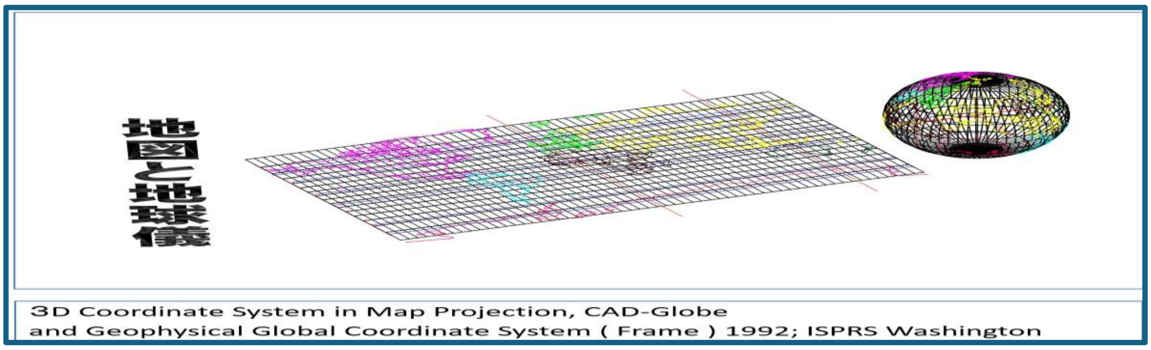


Fig. 1.02 CAD Globe -ISPRS Washington congress1992

CAD Globe was exhibited on AutoCAD 3D coordinate systems with both maps and 3D ellipsoidal globe to be displayed in mm to the range of the whole solar system.

Since 2000, GNSS satellites as earth control points, defining the gravity center of the earth as the origin of earth rotary ellipsoid coordinate system, geodetic network adjustments have realized the ground accuracy of 1cm. If only small numbers of national reference stations derived from IGS (International GNSS data Service: JPL, USA) worldwide reference stations, we could configure the national reference GNSS stations in Nigeria,Ghana and Mali in 5G-6G internet, so safe and secure.

1.1 ISO19152-Land Administration Domain Model：Ghana – Mali 3D mapping

ISO19152-Land Administration Domain Model will be finalized in FIG2026 congress; Cape Town – South Africa. We refer to this world standard for Ghana-Mali 3D mapping.

UTM 60 zones are mapped as Latitude Longitude rectangle map projection in AutoCAD map projection module, transforming Survey of India map grids and Japan UTM map grids.

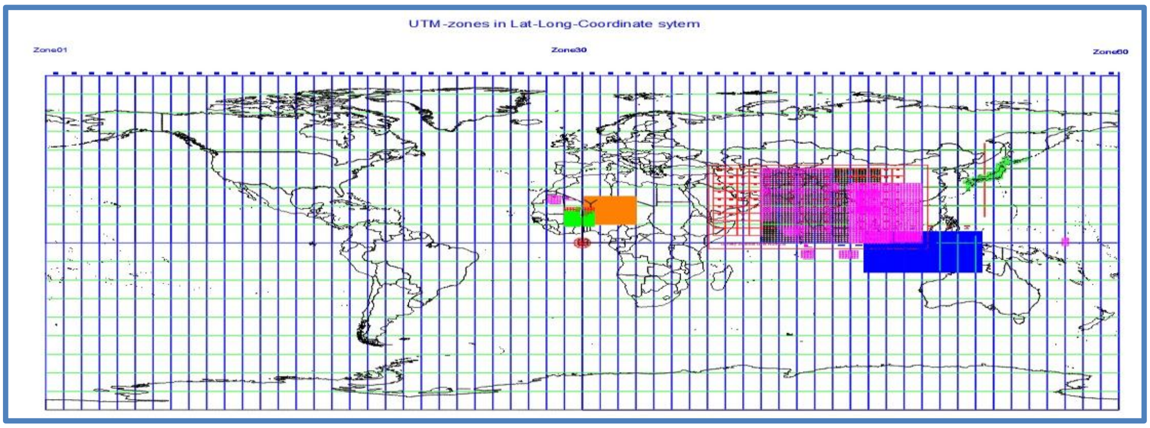


Fig. 1.11 UTM 60 zones-Latitude Longitude rectangle map projection in AutoCAD map projection module

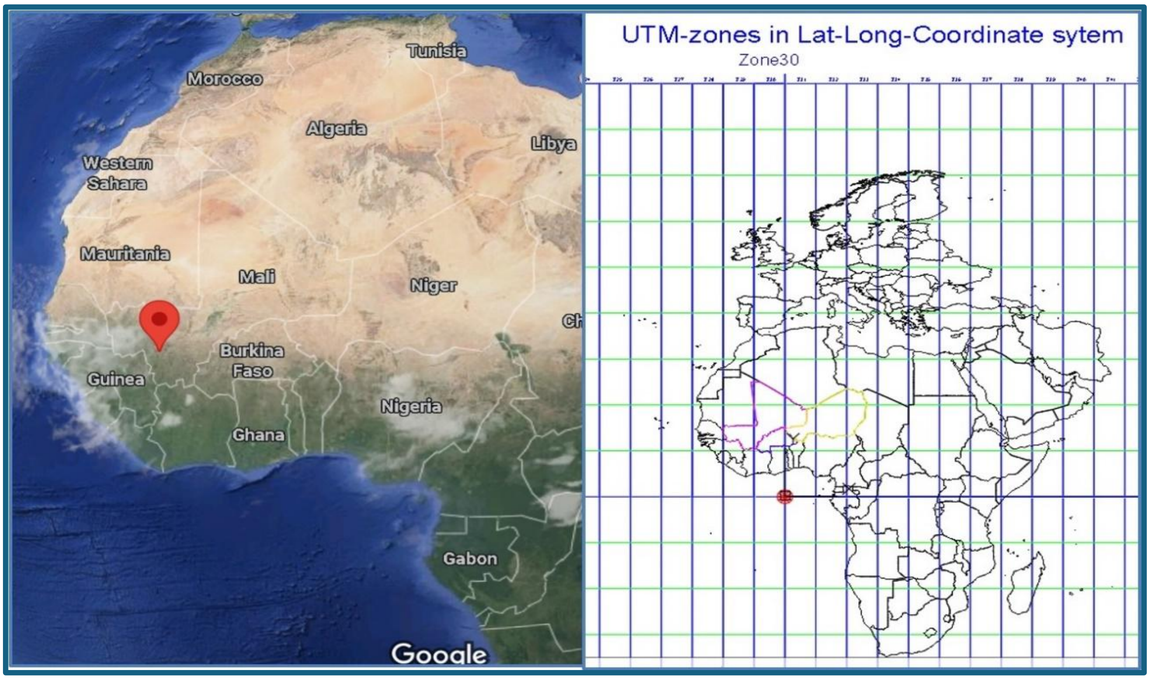


Fig. 1.12 Africa UTM zones in Latitude Longitude rectangle map projection

WGS84-LL84-Map Grids : Ghana- Burkina Faso-Mali-Niger-India have the followings;

(1) Prime geodetic datum: WGS84 reference ellipsoid

(2) Original map projection: Latitude-Longitude rectangle

(3) Basic map projection: Universal Transverse Mercator 60 zones

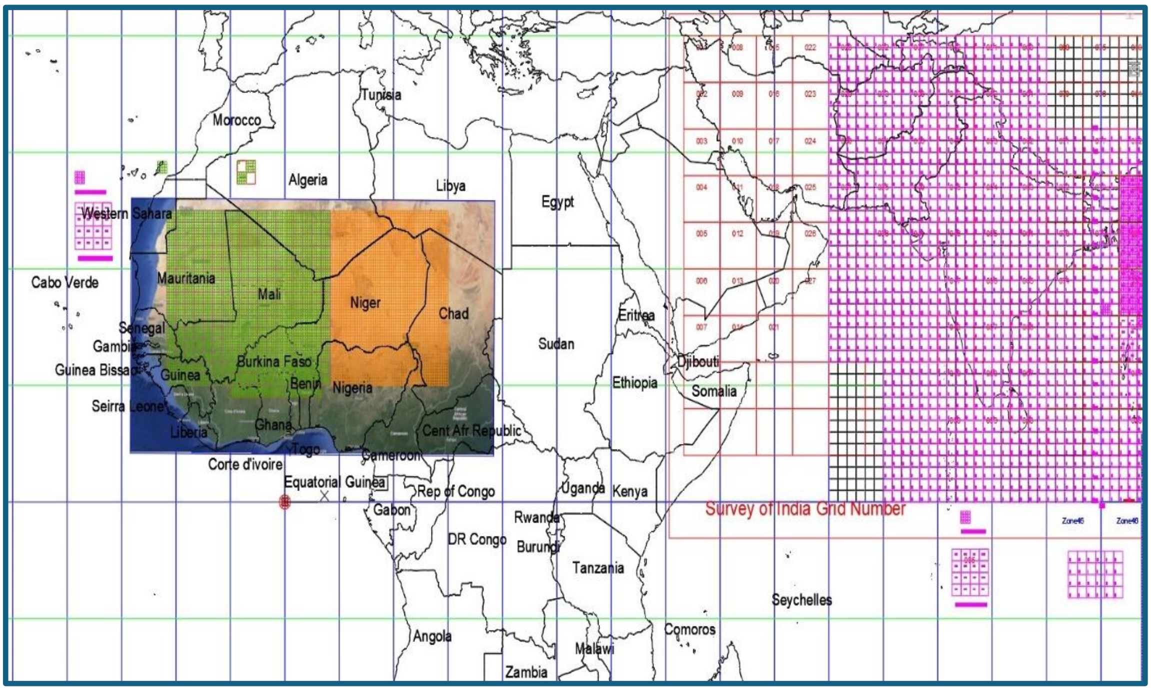


Fig. 1.13 WGS84-LL84-Map Grids :Nigeria-Ghana- Burkina Faso-Mali-Niger-India

UTM zones-Ghana-Burkina Faso-Mali and Niger-10K-mapgrids are divided into four zones, from 25K-mapgrids of 0.25 x 0.25 degree rectangle, according to classic grid numbering rule in 1960s.

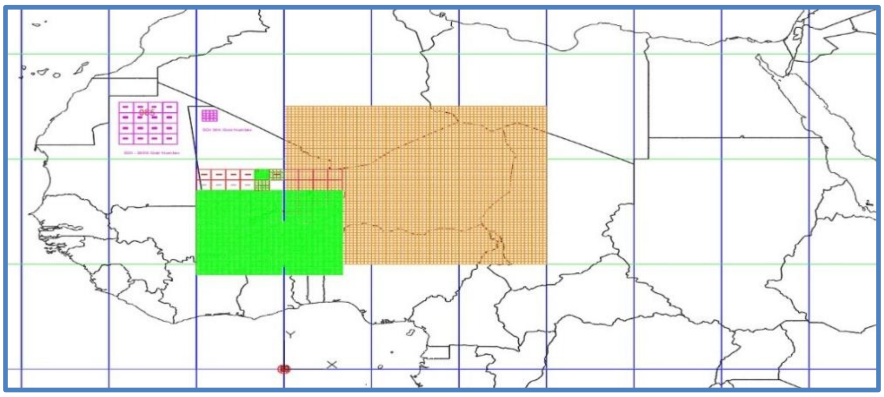
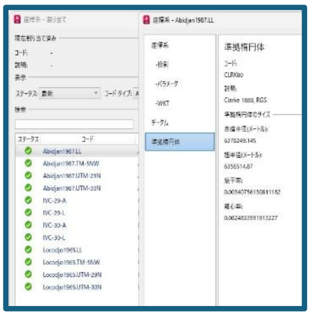
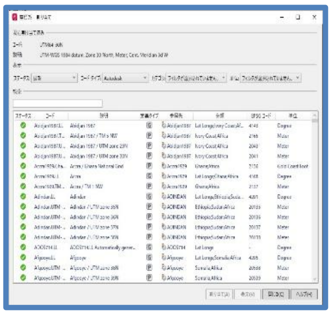


Fig. 1.13 UTM zones- 250K-50K-10K-mapgrids in Latitude Longitude rectangle map projection

To achieve equal-area map projection, original map projection: Latitude-Longitude rectangle map projection is to be transformed (map projected) by AutoCAD map projection module in a rigorous way of map projection. We could start with the old map projection, like Abidjan-1987-LL-Clarke1880 for Ghana – Mali as follows;





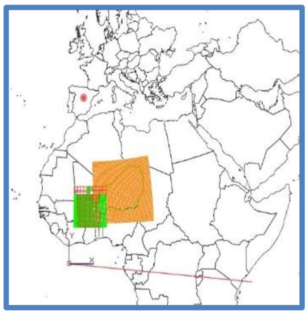


Fig. 1.14 Abidjan-1987-LL-Clarke1880

Fig. 1.15 WGS84-UTM30N-Ghana-Burkina Faso-Mali-Niger 2025

Fig. 1.16 UTM30N- Map Projection on AutoCAD Map : Ghana-Burkina Faso-Mali-Niger

WGS84-UTM30N-Ghana-Burkina Faso-Mali is now the standard referenced map projection.

UTM30N-Ghana-Burkina Faso-Mali-Niger is now defined on AutoCAD image map.

To generate 3D maps, terrain heights could be expressed as either terrain grid spot height or TIN (Triangulated Irregular Network) surface terrain heights in 3D-CAD (like AutoCAD).

CAD Globe has the essential components of digital GEO tiff style map images with Digital Elevation Model, like NASA-JAXA world 3D- 30m grid spot heights.

NASA-JAXA-30m-DEM covers worldwide and downloads could be done for Ghana – Mali countries area, to be formed with GEOtiff style map images, according to the WGS84 UTM map projections.

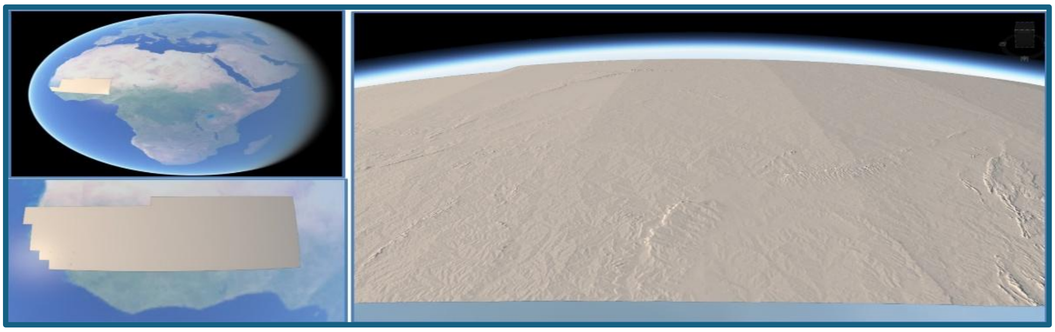


Fig. 1.18-1 NASA-JAXA-30m-DEM: Mali-Burkina Faso-Niger-Chad area

Map images of Ghana-Burkina Faso-Mali area is now derived from University of Texus,Austin; Map Library as 250K map series as follows;

Fig. 1.18-2 USA-2M maps in Abidjan-1987-LL-Clarke1880 -Ghana-Mali-Burkina Faso-Niger-1973

Fig. 1.18-3 USA-1973- 2M- 6maps : 2M-africa_index _map

USA-1973-2M-6maps are now unified and projected with 2M-africa_index _map. Also USA-1973-250K maps- Grids and Numbers are first defined in Abidjan-1987-LL-Clarke1880 map projection, and are to be transformed (projected) on WGS84-LL84 coordinate system in AutoCAD map module.

1.2 ISO19152-Land Administration Domain Model： Grids and Numbers

Classical map grids and numbers are started from Survey of India, based on the Indian "The Great trigonometrical Survey", which began on 10th April 1802 with the survey of a baseline near Madras, and was completed in 1871.

The essence is the reference ellipsoid (spheroid) and map projection map corner grid's latitude and longitude to be transformed and map projected in 3D CAD map projection module.

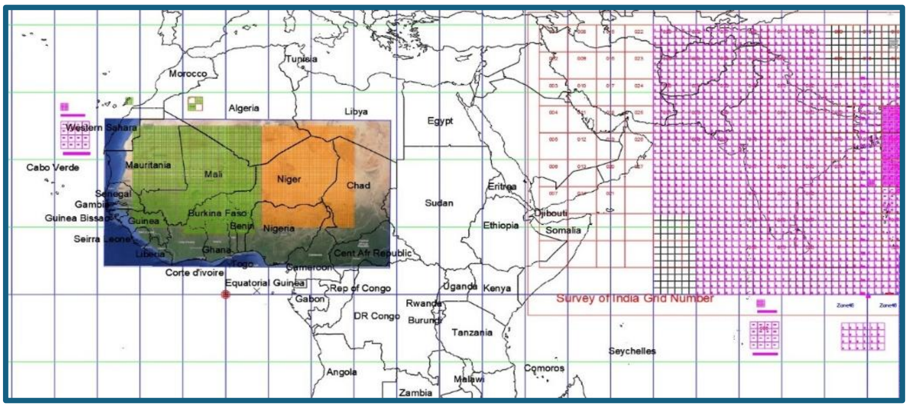


Fig. 1.21 Ghana- Burkina Faso- Mali-Niger-3D-mapping

- WGS84-UTM map projection zones

Now we could use the traditional grid and numbering rules in 1970s, based on the rigorous transformation and map projection process as follows;

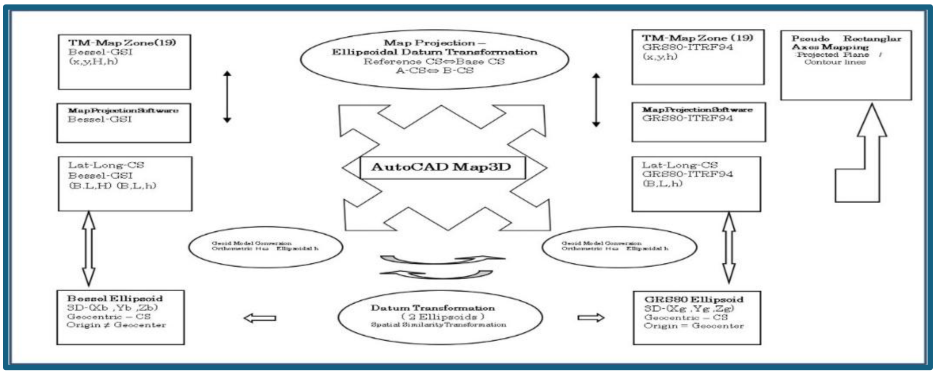
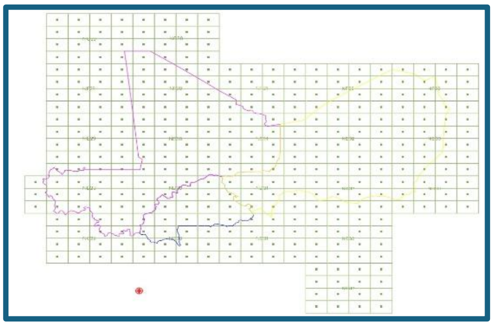


Fig. 1.22 Map projection and Ellipsoidal DATUM Transformation in Japan

Bessel1841 ellipsoid to GRS80 ellipsoid (Geo-Centric coordinate datum)

Ghana-Mali 3D mapping has the following map grid and numbering rules, according to USA mapping rule in 1970s, to be re-formalized in a rigorous way of map projection.



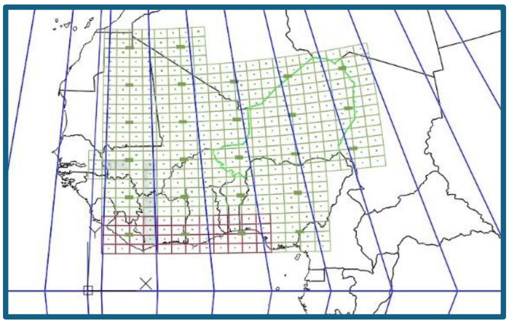


Fig. 1.23 USA-1973-250K maps- Grids and Numbers

Fig. 1.24 UTM29N-from Abidjan-1987-LL-Clarke1880

UTM29N in WGS84 ellipsoid is transformed from Abidjan-1987-LL-Clarke1880 in Latitude

Longitude rectangle map projection as follows, in AutoCAD map projection.

10K-numbering UTM29N is now defined on WGS84-LL84 map projection, to accept old and new grid and number rules for existing map sheets.

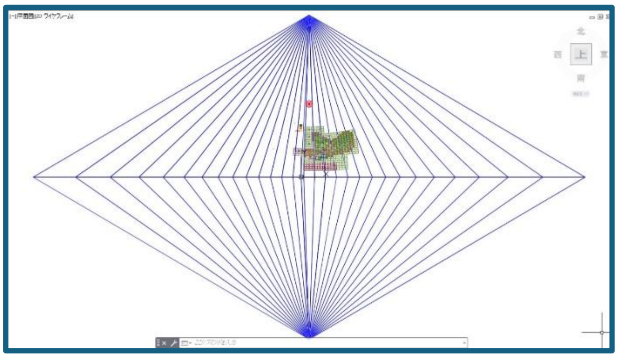


Fig. 1.25 10K-numbering UTM29N

1.3 Summary of current status:

ISO19152-LADM-Ghana-Burkina Faso-Mali-Niger - 3D cadastral and agricultural mapping is to be proposed in FIG2026- Cape Town- South Africa – congress for the final standard.

We could summarize now the following items;

1. Land Administration Mapping is based on WGS84-UTM projection maps of 1/10,000.
: AutoCAD-Map projection module; to WGS84-UTM 60 zones
; map scale 1/250,000 to 1/10,000

2. Boundary points have geo-centric coordinates from GNSS geodetic networking
, which has the origin at earth gravity center as the focus of an ellipse of GNSS trajectory.
: IGS global 500 stations combined national reference GNSS stations; 50kms interval

3. Existing aerial photos are to be digitalized into high resolution images
for bundle triangulation for 3D digital image models on 3D display with / without glasses.
: Instead satellite image stereo 3D mapping on Summit Evolution(AutoCAD) - 3D display

4. For official archive, 3D digital image models and 3D image maps, as historical reality,
are to be displayed on PC screen, measured and archived as title of land ownership.
; sustained by GNSS satellite networking, aerial / satellite photogrammetry
and Least square adjustment based on map projections.
; 3D CAD mapping school in Osaka/ Ghana/Mali

5. Map projections are based on USGS- Map projection working manual,
and realized on 3D CAD/GIS systems, transforming ground accuracy of GNSS surveying.
: Ground unit in mm; Ground accuracy of GNSS geodetic networking in cm

6. CAD-Globe, Google Earth like presentation, is 3D diorama model maps for land design and construction on modern construction / forestry machines, as 3D mapper.

: Historical maps are to be transformed digitally to 3D DX maps, as Historical Reality, unified by 4D Image Map Archive Designed Aerial Studies (IMADAS).

Chapter 2. 3D DX(Forest) Map DGPS Satellite Survey

: 3D Diorama Model Creation Method

3D Forest Map DGPS Satellite Survey for 3D Diorama Model Creation Method was conducted in Kyoto University Kamigamo Test Site, using Control Point 1 and Control Point 2.

DGPS-Garmin receiver and antenna on the roof of Suzuki Jimny-car took 1sec- GXGYGZ coordinates into AutoCAD-DXF files to 3D forest map.

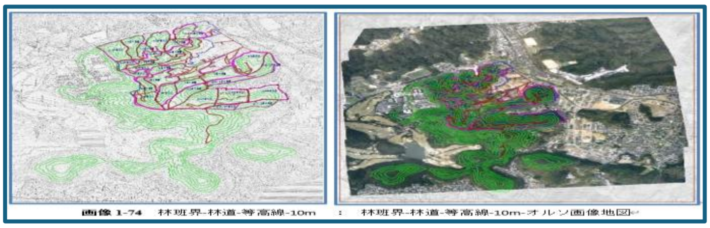


Fig. 2.01 DGPS-3D mapping: Kyoto Univ. Kamigamo research forest

Fig. 2.02 DGPS satellite survey - forest compartment map - ortho image

DGPS satellite survey - 3D topographical mapping in Kyoto University Kamigamo Research Forest was prepared with forest compartment map - ortho image.

For DGPS-3D topographical mapping in Kyoto University Kamigamo Research Forest, Forest compartment maps were unified into UTM map system, and DGPS-1 second-walking and Driving routes are projected in 3D forest map.

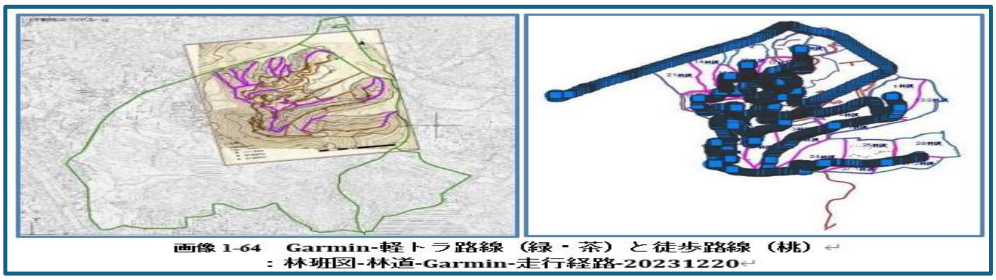


Fig. 2.03 DGPS-3D topographical mapping

-Kyoto University Kamigamo Research Forest

-Forest compartment map-DGPS-1 second-Driving route

For 3D mapping, NASA-JAXA global 30m DEM is now introduced in AutoCAD Infraworks for CAD Globe presentation, to design the infrastructure and to drive(move) construction machines.

Fig. 2.04 Forestry vehicle 3D mapping : Komatsu harvester - GNSS-TLS

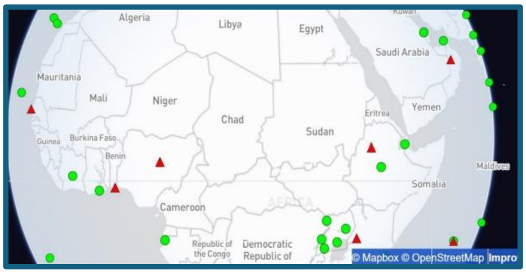
Fig. 2.05 Komatsu Harvester-cutting Komatsu Forest : Singen excursion;2019.09.20

3D-CAD map is well combined with forestry machines, and teaching operator is advanced in Japan.

2.1 UN-GGIM and UN-GGRF oriented 3D mapping in Cambodia

Before Ghana – Mali 3D mapping, we investigated the current GNSS reference stations in the world, via IGS network in FIG2025 Working Week, Brisbane-Australia. For GNSS geodetic networking, we selected German standard software: “PANDA” as a candidate software of reference stations adjustment, since German official reports used this software as standard.

UN-GGIM and UN-GGRF have organized IGS-world-500 reference stations. So we could add more reference stations in Ghana and Mali and other countries.



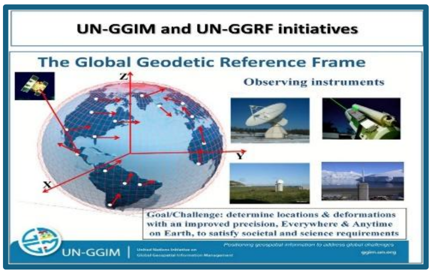
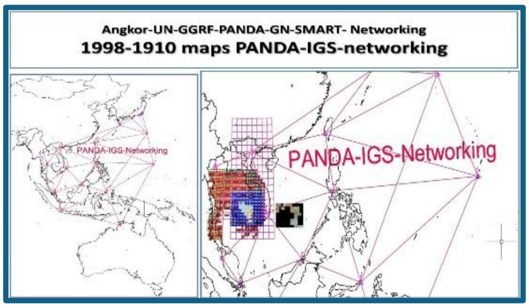


Fig. 2.11 IGS-world-500 reference stations-in Africa

Fig. 2.12 UN-GGIM and UN-GGRF

As a proposed example, Angkor-UN-GGRF geodetic networking was planed with PANDA and GN-SMART software for APSARA authority organization.



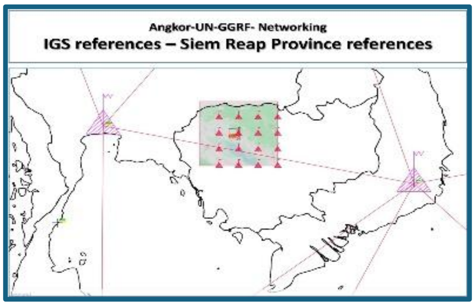


Fig. 2.13 PANDA-IGS-networking

Fig. 2.14 Siem Reap province networking

2.2 Large scale 3D cadastral mapping, using Differential GPS Surveying

Parallel with the nationwide GNSS geodetic network adjustment, the first step of 3D large scale mapping of Ghana could be learned from the experience of Angkor DGPS mapping in 2016.

The process was presented in FIG Working Week 2019 Hanoi, Vietnam.

For 1/5,000 or larger map scales, we could use DGPS with the accuracy 2- 3m on the ground.

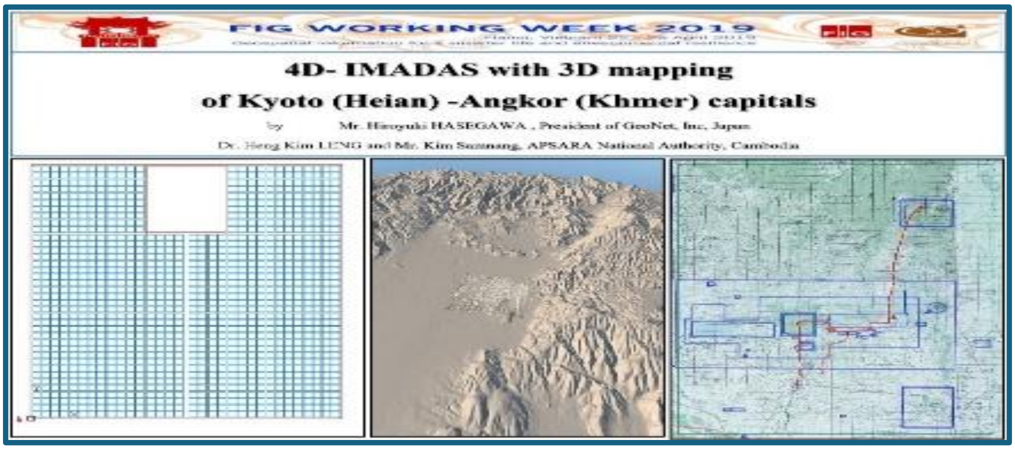
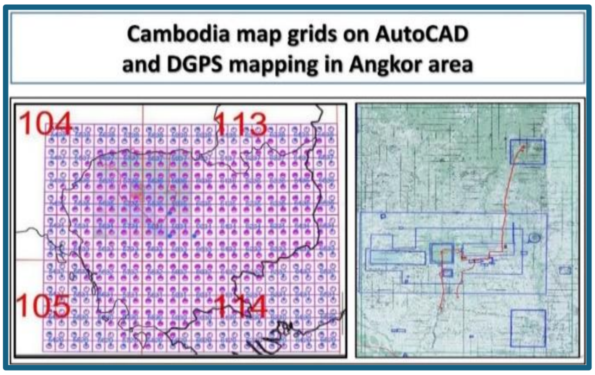


Fig. 2.21 Heian(Japan)-Khmer(Cambodia)-palaces in 9th ce.

Fig. 2.23 Angkor DGPS mapping



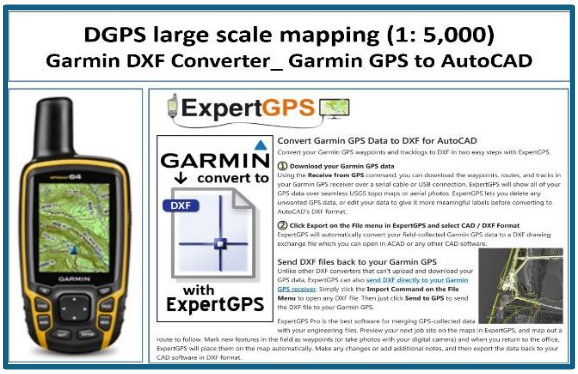


Fig. 2.24　DGPS　mapping Cambodia Angkor Wat : (2016.11.30)

1 sec (GX / GY / GZ) coordinates to AutoCAD MapMobile Mapper/ Garmin DGPS mapper

Fig. 2.24　Garmin-DGPS-ExpertGPS

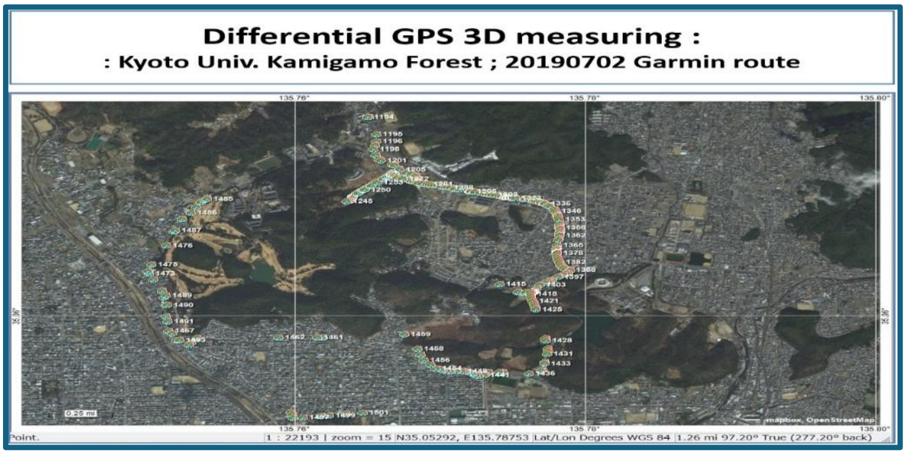
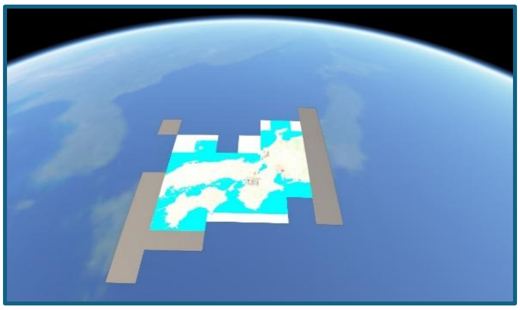


Fig. 2.25　Garmin-DGPS-ExpertGPS-Kyoto Univ

Chapter 3.　Vintage aerial photos(1970)
– automatic bundle triangulation of Fukui prefecture

In 2000s, Kyoto University researchers asked GeoNet to generate 3D aerial photo model of Burkina Faso on digital stereo plotter: Summit Evolution. In FIG2025 Brisbane, the authors presented a paper on automatic bundle triangulation of Fukui prefecture in 1970.



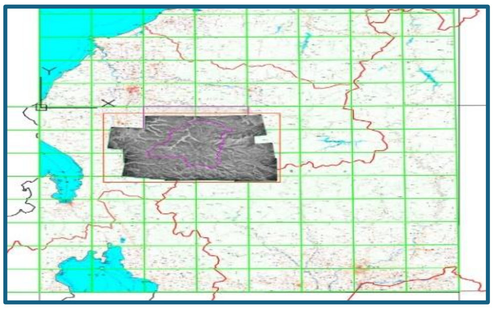


Fig. 3.01 CAD-Globe-JAXA-30mDEM-2000-200K map images

Fig. 3.02 Fukui prefecture- Ikeda town -1970 bundle triangulation

Fukui prefecture forest basic maps are draped on JAXA 30m DEM for forestry boundary map and logging load designing as CAD Globe on AutoCAD-Infraworks show/measure/archive system.

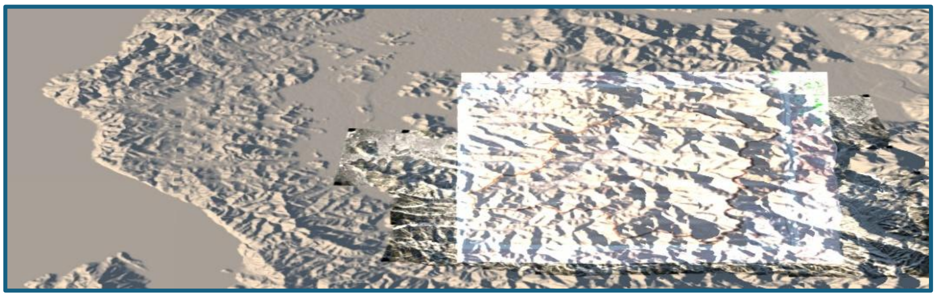


Fig. 3.03 Fukui prefecture- Ikeda town -CAD Globe- logging road design

For the final target of 3D mapping in Land Administration, especially forest administration, the unit forest land parcels and individual trees are to be registered as inventory items with essential attributes in asset register on 3D-DX map (3D CAD map) as legitimate title of land registration. The most advanced institutes are University of Goettingen; Germany and Faculty of Forestry; University of British Columbia; Canada.

Chapter 4. Satellite photogrammetry

3D mapping for wide area in the world needs 3D image models from satellite photogrammetry.

We have already made 3D photogrammetric models on digital stereo plotter; Summit Evolution (AutoCAD version) with 3D display to be displayed/ measured/ archived as 3D CAD map.

Fig. 4.01 Satellite Photogrammetry of Kyoto University: ACRS2017-presentation

Fig. 4.02 TIN Surface modeling in AutoCAD-Civil3D : INPHO- 3D diorama

As the final product of 3D mapping, 3D diorama model on CAD Globe is produced.

For satellite photogrammetry, we have been negotiating with the Survey of India for satellite stereo images worldwide. We have made SPOT, IKONOS, ALOS stereo images for accuracy evaluation, starting from 1995 Kobe earthquake research projects.

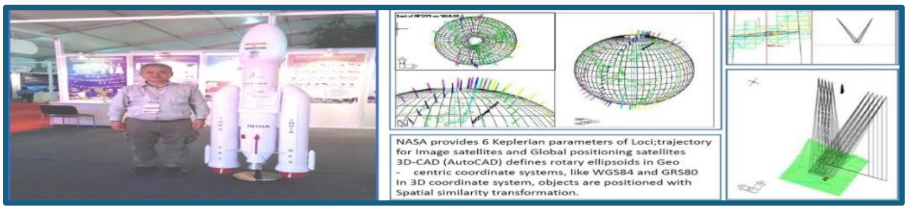


Fig. 4.03 ACRS2017-Indian Satellite

Chapter 5. Regulations and Specifications (draft)

Since 2011, we have been preparing for practical regulations and specifications, negotiating with governmental authorities, based on Regulatory Exemption Regulations, starting from Land Survey Act and the Cadastral Survey Work Regulations, as follows;

Fig. 5.01 Regulation-German-translated: Gauss bust (LGLN, Germany)

Fig. 5.02 Regulation-forestry-Japanese-English-German-draft

Fig. 5.03 3D mapping Regulation-draft: Osaka active faults, CORS and GNOK stations

For 3D forest mapping, Forestry Agency - Measurement regulations, forest road regulations, map regulations are now introduced in AutoCAD mapping layer templates.

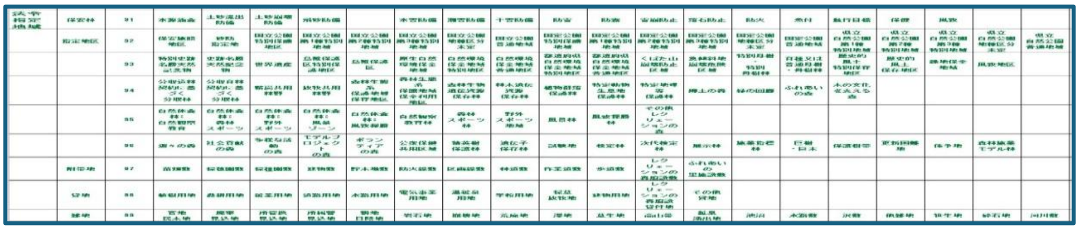


Fig. 5.04 AutoCAD mapping layer template for 3D forest mapping

Acknowledgements

This research paper has been supported by achievements of German authentic satellite geodesy. The author would like to express deep gratitude to Dr. Guenter Seeber and Dr. Gerhard Wuebbena, in the theoretical and practical sense. Practices will be reflected to Japanese cadastral regulations and forestry specifications, applied to forestry administration and national land survey projects.

References: all are now translated in Japanese by the author.

Bauer, Rainer et.al. (2015).
“Das deutsche Vermessungs- und Geoinformationswesen 2015” ; Wichmann.
Luhmann, Thomas (2018). “Nahbereichsphotogrammetrie” ; Wichmann.
Niemeier, Wolfgang (2008). “Ausgleichungsrechnung”; Walter de Gruyter
Seeber, Guenter (2003). “Satellite Geodesy “; Walter de Gruyter

BIOGRAPHICAL NOTES

Erdoo Paula Awai is an environmental scientist and policy-oriented researcher with dual Master’s degrees in Development Practice and Biodiversity and Ecosystem Services (Science–Policy Interface), and PhD-level training in Environmental Sciences (Sustainable System Sciences) of Osaka Metropolitan University.

Hiroyuki Hasegawa obtained a BA in Human Geography in 1971 from Kyoto University, Japan.
In 1976 he was graduated from ITC, The Netherlands as Photogrammetric Technologist.
From 1971 until 1999 he worked at PASCO Corporation in Tokyo, Japan.
From 1999 until now he is working in GeoNet, Inc. as CEO, in Osaka, Japan.
From 2013 he was the researcher of Graduate School
of Asian and African Area Studies Kyoto University, Japan.
From 2014 to 2015 he was the representative of common research project

of CSEAS (Center for Southeast Asian Studies Kyoto University)
: “4D IMADAS for Williams Hunt Collection”.

In FIG Working Week 2019 Hanoi, he presented the paper
:4D-IMADAS with 3D mapping of Kyoto (Heian) – Angkor (Khmer) capitals

In FIG Working Week 2025 Brisbane, he presented the paper
:Fukui City - 3D-Cadastral Map and Kyoto University - 3D-Forest Map
based on 4D-Image Map Archive Designed Aerial Survey

CONTACTS

Hiroyuki Hasegawa : CEO; GeoNet, Inc.
Higashi-Nakajima 1-5-25-608, Higashi-Yodogawa- ward Osaka; Japan
Tel. +81-090-2148-0501 Email: hasegawa@geonetz.com