INTISARI

Pembangunan objek spasial kadaster Tiga Dimensi (3D) menghadapi tantangan dalam hal teknik akuisisi data 3D, tingkat kompleksitas objek 3D, dan representasi objek spasial kadaster 3D. Representasi tersebut antara lain berupa penentuan posisi yang akurat (terletak di atas atau di bawah permukaan tanah) dan tingkat kedetilan objek. GNSS CORS yang tersedia saat ini dapat digunakan untuk akuisisi data kadaster 3D, namun komponen vertikalnya berupa tinggi geometrik tidak memiliki realisasi fisik di bumi karena mengacu pada referensi matematis bumi, yaitu elipsoid. Kadaster 3D memerlukan tinggi ortometris yang memiliki realisasi fisis di bumi yang mengacu pada bidang referensi fisis bumi, yaitu geoid. Pendefinisian geoid teliti untuk representasi kadaster 3D mempunyai beberapa kendala, di antaranya ketersediaan dan distribusi data gaya berat. Salah satu solusi yaitu melalui pendefinisian geoid lokal dengan cakupan wilayah relatif sempit dan penggunaan model geopotensial global terbaru. Berdasarkan permasalahan tersebut, penelitian ini bertujuan untuk mengembangkan metode akuisisi data objek kadaster 3D berbasis tinggi ortometrik dengan mendefinisikan geoid lokal dan mengintegrasikan teknologi GNSS CORS dengan TLS untuk untuk menghasilkan representasi spasial objek kadaster 3D yang kompleks dengan lengkap, handal, dan teliti.

Penelitian dilakukan di Daerah Istimewa Yogyakarta dengan mempertimbangkan kondisi geologi, topografi, dan pelaksanaan administrasi pertanahan untuk kadaster 3D. Data utama yang digunakan berupa data sekunder GNSS CORS, data gaya berat terestris, dan model geopotensial global, serta data primer ukuran 4 (empat) objek kadaster 3D. Tahapan penelitian meliputi 1). Pendefinisian referensi horizontal melalui pendefinisian ulang koordinat *base station* GNSS CORS dan kalibrasi *receiver base station*, 2). Pendefinisian referensi tinggi berupa model geoid lokal, menggunakan 4 (empat) strategi hasil kombinasi dua Model Geopotensial Global (MGG) terbaru, SGG-UGM-1 dan GO_CONS_GCF_2_SPW_R5, dengan 2 (dua) distribusi titik kontrol, menggunakan metode perhitungan *Remote Compute Restore* (RCR), 3). Akuisisi dan pemodelan objek kadaster 3D dengan TLS yang direferensikan terhadap titik ikat yang sudah didefinisikan terhadap referensi horizontal GNSS CORS dan referensi vertikal geoid lokal. Evaluasi hasil penelitian dilakukan dengan analisis kuantitatif dengan teknik komparasi geometris dan analisis visual.

Hasil penelitian pendefinisian referensi horizontal menunjukkan koordinat *base station* GNSS CORS tahun 2017 berbeda signifikan dibanding tahun 2011 dan 2015, dengan perbedaan rata-rata komponen X, Y, dan Z sebesar 15,915 cm, -4,952 cm, dan 7,122 cm berturut-turut dengan pergeseran ke arah tenggara. Uji *zero base line* untuk kalibrasi *receiver* GNSS CORS menunjukkan *slope distance* di 3 (tiga) *base station* tidak memenuhi kriteria yang disyaratkan (>3 mm), yaitu *receiver* Kabupaten Gunungkidul, Kulonprogo, dan Purworejo. Sedangkan yang memenuhi syarat (<3 mm) yaitu *receiver* Kabupaten Bantul dan Sleman. Hasil evaluasi pendefinisian geoid dengan 4 (empat) strategi menunjukkan model geoid lokal terbaik diperoleh dari strategi 3 dengan standar deviasi 0,137 m terhadap geoid geometrik. Evaluasi penggunaan titik referensi GNSS-ortometrik pada pengukuran objek kadaster 3D dengan TLS menunjukkan toleransi nilai RMSE sesuai dengan spesifikasi alat ukur TLS BLK 360 sebesar 0,024 m, dan uji perbedaan volume <10% pada 226 sampel sebesar 92,66%. Ketelitian geometrik vertikal (ketinggian) hasil pemodelan kadaster 3D dengan georeferensi dengan tinggi ortometrik memenuhi ketelitian vertikal kriteria kelas 1 mengacu *United States National Map Accuracy Standards* (USNMAS). Pengembangan

pengukuran objek kadaster 3D berbasis tinggi ortometrik dengan memanfaatkan teknologi GNSS memberikan kontribusi positif dalam hal pendefinisian posisi 3D secara absolut, ketelitian pengukuran titik ikat dan objek, serta pemodelan dan visualisasi kadaster 3D.

Kata kunci: GNSS CORS, geoid, model 3D, kadaster 3D

ABSTRACT

The development of three-dimensional (3D) cadastre spatial objects faces challenges in terms of 3D data acquisition techniques, the level of complexity of 3D objects, and the representation of 3D cadastre spatial objects. The representation includes accurate positioning (located above or below the surface) and the level of detail of objects. The currently available Global Navigation Satellite Systems Continuous Operating Reference System (GNSS CORS) can be used for 3D cadastre data acquisition, but the vertical component in the form of geometric height has no physical realization on earth because it refers to the earth's mathematical reference, namely the ellipsoid. For 3D cadastre, an orthometric height is required which has a physical realization on the earth which refers to the earth's physical reference surface, namely the geoid. The precise definition of geoid for 3D cadastre representation has several constraints, including the availability and distribution of gravity data. One solution is to define a local geoid with a relatively narrow area coverage and the use of the latest global geopotential model. Based on these problems, this study aims to develop a method of data acquisition for 3D cadastre objects based on orthometric height by defining local geoids and integrating GNSS CORS technology with TLS to produce a complete, reliable, and accurate spatial representation of complex 3D cadastre objects.

The research was conducted in the Special Region of Yogyakarta by considering geological conditions, topography, and the implementation of land administration for 3D cadastre. The main data used are GNSS CORS secondary data, terrestrial gravity data, and global geopotential models, as well as primary data of 4 (four) 3D cadastre objects. The research stages include 1). horizontal reference definition through redefining CORS GNSS base station coordinates and calibration of *base station receivers*, 2). definition of high reference in the form of a local geoid model, using 4 (four) strategies resulting from the combination of the two latest Global Geopotential Models (GGM), SGG-UGM-1 and GO_CONS_GCF_2_SPW_R5, with 2 (two) distribution control points, using the *Remote Compute Restore* (RCR) calculation method), 3). acquisition and modeling of 3D cadastre objects with TLS referenced against predefined binding points against GNSS CORS horizontal references and local geoid vertical references. Evaluation of research results was carried out by quantitative analysis with geometric comparison techniques and visual analysis.

The results of the horizontal reference definition study show that the coordinates of the GNSS CORS *base station* in 2017 are significantly different from 2011 and 2015, with an average difference of the X, Y, and Z components of 15.915 cm, -4.952 cm, and 7.122 cm, respectively, with a shift to southeast direction. The zero base line test for GNSS CORS receiver calibration shows that the slope distance at 3 (three) base stations does not meet the required criteria (>3 mm), namely the receivers of Gunungkidul, Kulonprogo, and Purworejo Regencies. While those who meet the requirements (<3 mm) are the receivers of Bantul and Sleman Regencies. The results of the evaluation of geoid definition using 4 (four) strategies, showed that the best local geoid model was obtained from strategy 3 with a standard deviation of 0.137 m to the geometric geoid. Evaluation of the use of GNSS-orthometric reference points for measuring 3D cadastre objects using TLS shows the RMSE tolerance value according to the specifications of the TLS BLK 360 measuring instrument is 0.024 m, and the volume difference test is <10% on 226 samples of 92.66%. The vertical geometric accuracy (height) of the 3D cadastre modeling with georeferenced using orthometric height meets the vertical accuracy of class 1 criteria referring to the *United States National Map Accuracy Standards* (USNMAS). The development of 3D cadastre

survey with an orthometric height using GNSS technology has made a positive contribution in terms of absolute 3D position definition, accuracy of measurement of ground control points and objects, as well as 3D cadastre modeling and visualization.

Keywords: GNSS CORS, geoid, 3D model, 3D cadastre