DEM GENERATION TO SUPPORT CARBON ACCOUNTING SYSTEM

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INTRODUCTION

National importance of monitoring forest for carbon accounting in Indonesia

- Land clearing and forestry are significant components of Indonesia’s emissions profile.

- A high quality, credible carbon accounting system needs to be established to show the success of REDD policies and interventions.

- INCAS will provide a comprehensive and credible account of Indonesia’s land based emissions profile and sinks capacity.

Source: Second National Communication on Climate Change (2009)
REMOTE SENSING COMPONENT OF INCAS

Develop capacity to undertake a wall-to-wall historical assessment of land cover change from 1999 to 2010

Landcover mapping process

- Scene Selection
- Ortho-rectification, sun correction and Terrain-illumination correction
- Quality Assurance
- Cloud Masking and Mosaicing
- Classification single data
  - Manually set base
  - Automatically ‘match’ other years
- Multi-temporal processing to monitor change
SAMPLE RESULTS OF DATA CORRECTION STAGE

Orthorectification

Terrain correction

Digital Elevation Model
LIMITATION OF DEM SRTM

**DEM SRTM C band**: Spatial → 90 m (low)
Accuracy → 5-16 m (Yastikh et al., (2006), Tighr et al., (2009))

**DEM SRTM X band**: Spatial → 30 m (detail)
Accuracy → 3-6 m (Gesch et al., (2005), Yastikh et al., (2006))

**Limitation**

- SRTM C band → global coverage but low resolution
- SRTM X band → not cover all Indonesia
- Missing data and error in SRTM data
- SAR: Layover, shadow, atmosferic effect (temporal decorrelation) (Karkee et al., 2006)
OPTICAL SATELLITE (ALOS)

- ALOS have been lunched on 24 January 2006. It is equipped by PRISM which has 3 telescopes (spatial 2.5 m) for forward, nadir, backward enabling us to generate DEM.
- ALOS 3 will be lunched in 2014. It is equipped by Optical Pancromatic which has 2 telescopes for nadir (0.8 m) and backward (1.25 m) → DEM

(Sumber: JAXA)

Another alternative source to provide high resolution DEM to support carbon accounting system (data correction stage)
OBJECTIVE

1. To generate high resolution Digital Elevation Model (DEM) using ALOS PRISM stereo data

2. To improve the quality of the generated DEM from ALOS PRISM.
METODOLOGY: LOCATION AND DATA

DATA:
- ALOS PRISM level 1B2R, Nadir and Backward
- GCP from field measurement (Input and verification data)
- SRTM X-C band spatial 30 m
DEM GENERATION METHOD

- Stereoscopic image
  - Geometric model: Generic Pushbroom
    - Setting & pyramid layer
      - Sensor Model
        - Data information
          - Sensor characteristic

  - GCP Measurement
    - GCP (XYZ)
      - GCP collection

    - Tie Point making and checking
      - 50-60 tie points

    - 2 Times
      - Final: 77 CP

  - Triangulation process
    - Error information
      - Less than 0.5 pixel

  - DEM Generation
    - DEM
GCP COLLECTION (BASED ON GROUND MEASUREMENT)

- Collect GCP (XYZ) from ground measurement

Differential GPS (Base and rover)

GCP 8

- 21 GCP as input data to generate DEM
- 14 GCP for accuracy evaluation

Location
DISTRIBUTION OF GCP/CP
DEM GENERATION PROCESS

RMSE of GCP (Triangulatius results)

<table>
<thead>
<tr>
<th>Summary RMSE for GCPs and CKXs (number of observations in parenthesis):</th>
<th>Control</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground X:</td>
<td>0.000106 (77)</td>
<td>0.000000 (0)</td>
</tr>
<tr>
<td>Ground Y:</td>
<td>0.000087 (77)</td>
<td>0.000000 (0)</td>
</tr>
<tr>
<td>Ground Z:</td>
<td>0.438942 (77)</td>
<td>0.000000 (0)</td>
</tr>
<tr>
<td>Image X:</td>
<td>0.3399161 (154)</td>
<td>0.000000 (0)</td>
</tr>
<tr>
<td>Image Y:</td>
<td>0.4183694 (154)</td>
<td>0.000000 (0)</td>
</tr>
</tbody>
</table>

Estimation of Exterior Orientation (Triangulation results)

<table>
<thead>
<tr>
<th>Image parameter value:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image id 2:</td>
</tr>
<tr>
<td>X: 1.13218015e+004 2.8671575e+002 -1.0040404e-002</td>
</tr>
<tr>
<td>y: -4.40501026e+003 -3.18084026e+002 2.99225795e-002</td>
</tr>
<tr>
<td>z: 6.92231678e+005 -2.22231933e+001 -5.11971871e-001</td>
</tr>
<tr>
<td>omega: 6.15038341e-003 9.63570000e-004</td>
</tr>
<tr>
<td>phi: 1.69117296e-002 3.09126329e-004</td>
</tr>
<tr>
<td>Kappa: -2.13811162e-001 2.31753894e-006 7.52929351e-007</td>
</tr>
<tr>
<td>Image id 1:</td>
</tr>
<tr>
<td>X: -5.52047123e+004 3.39536171e+002 1.07078672e-002</td>
</tr>
<tr>
<td>y: -3.29469585e+005 -1.549017031e+002 2.26157227e-001</td>
</tr>
<tr>
<td>z: 6.06156008e+005 -2.68751736e+002 -4.22137875e-001</td>
</tr>
<tr>
<td>omega: 4.99445846e-001 8.28523959e-004</td>
</tr>
<tr>
<td>phi: -7.91871574e-002 3.01551867e-004</td>
</tr>
<tr>
<td>Kappa: -1.81987058e-001 8.15801927e-005 7.6365504e-007</td>
</tr>
</tbody>
</table>

Accuracy Information of the generated DEM

<table>
<thead>
<tr>
<th>Accuracy Information</th>
<th>Global accuracy:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Accuracy:</td>
<td></td>
</tr>
<tr>
<td>Total # of 3D Reference Points Used: 72</td>
<td></td>
</tr>
<tr>
<td>Minimum, Maximum Error: -12.5207, 11.9371</td>
<td></td>
</tr>
<tr>
<td>Mean Error: 0.1478</td>
<td></td>
</tr>
<tr>
<td>Mean Absolute Error: 3.1602</td>
<td></td>
</tr>
<tr>
<td>Root Mean Square Error (RMSE): 3.6720</td>
<td></td>
</tr>
<tr>
<td>Absolute Linear Error 90 (LE90): 6.1178</td>
<td></td>
</tr>
<tr>
<td>HIMA Absolute Linear Error 90: 4/- 6.0392</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACCURACY INFORMATION</th>
<th>General Mass Point Quality:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent % (1.0-0.85): 60.9674</td>
<td></td>
</tr>
<tr>
<td>Good % (0.85-0.70): 25.3050 %</td>
<td></td>
</tr>
<tr>
<td>Fair % (0.70-0.5): 0.0000 %</td>
<td></td>
</tr>
<tr>
<td>Isolated %: 0.0000 %</td>
<td></td>
</tr>
<tr>
<td>Suspicious %: 13.6288 %</td>
<td></td>
</tr>
</tbody>
</table>
DEM FROM ALOS PRISM

- Based on GCP ground measurement

(a) The generated DEM from ALOS stereo data

(b) Image quality of the generated DEM

- Excellent (>0.85%)
- Good (0.70–0.85%)
- Fair (0.50–0.70%)
- Isolated
- Suspicious

Bull eyes
DIFFERENCE OF GCP NUMBERS IN DEM GENERATION

21 GCP

16 GCP

10 GCP

5 GCP

Relative error to GCPs (m)

Error increases significantly at DEM with 5 GCP
DIFFERENCE OF SPATIAL RESOLUTION IN DEM GENERATION

GCP = 21

Relative error to GCPs (m)

Error

Low spatial resolution →
Reduce “bull eyes” but
decrease information detail
QUALITY IMPROVEMENT OF DEM ALOS PRISM USING DEM FUSION METHOD
METHOD TO DETECT “BULL EYES”

Window 5x5 pixels, centered on c

<table>
<thead>
<tr>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Point C is peak if:

- C must be taller than all other points in the box.
- C must be taller than the spire height than the 8 points marked by "x".

Spire

Pit
QUALITY ANALYSIS OF DEM FROM ALOS PRISM

DEM OF ALOS (10m)

Very Detail

DEM OF SRTM (30m)

Low detail

Bull eyes: Pit (Red) and Spire (Green)

many

Pit (Red) : 3687
Spire (Green): 201

Less

Pit (Red) : 9
Spire (Green): 7
DEM FUSION METHOD

Geoid correction (EGM 2008)

Co-registration & normalization

DEM ALOS

SRTM

Contouring

Height error map

Height error map

Layer stacking

Weighted Mean Height

Final DEM

- Standard deviation relative to referenced model

Weighted Mean Height (Hoja et al., 2006)

\[ h_{out} = \frac{\sum h_i \cdot p_i}{\sum p_i} \]

\[ p_i = \frac{1}{a_i} \] (\( a_i \) is given accuracy)

\( h_i \): Height DEM (1,2)
\( a_i \): Accuracy DEM (1,2)
GEOID CORRECTION TO EGM 2008

✓ Geoid Correction to EGM 2008
- DEM co-registration (referenced DEM: DEM of ALOS)
- Height Normalization (referenced DEM: DEM of ALOS)

DEM (EGM 2008) = DEM (EGM 96) + EGM 96 - EGM 2008

Height difference is about 0-3 m
CO-REGISTRATION AND HEIGHT NORMALIZATION

- Geoid correction to EGM 2008
- DEM co-registration (referenced DEM: DEM of ALOS)
- Height Normalization (referenced DEM: DEM of ALOS)

**Quality assessment:**
RMSE < 1 pixel
DEM ALOS : Red Layer
DEM SRTM : Green Layer

DEM Output =
(STDEV Output/STDEV Input) (DEM Input – Rata-rata Input) + Rata-rata Output

DEM of ALOS (10m)

DEM of SRTM (30m)
HEIGHT ERROR MAP
(STANDAR DEVIAION FOR EACH PIXEL)

DEM of ALOS (10m)

DEM of SRTM (30m)

Low Error

High Error
RESULT OF DEM FUSION (SPASIAL 10M)

DEM of ALOS (10m)

Bull eyes

Error map

DEM FUSION (10m)

Bull eyes

Error map

Decrease 66%

Increase 10% (>3σ)
EVALUATION OF “BULL EYES” AND ACCURACY

Improvement of “Bull eyes”

<table>
<thead>
<tr>
<th></th>
<th>3888</th>
<th>1733</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEM ALOS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEM Fusion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

66%

Improvement of DEM Accuracy

GCP from field measurement

Using Least Squared Adjustment

<table>
<thead>
<tr>
<th>DEM</th>
<th>Akurasi (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEM ALOS PRISM</td>
<td>7.6</td>
</tr>
<tr>
<td>DEM Fusion</td>
<td>7.3</td>
</tr>
</tbody>
</table>

Quality and Accuracy are increase!
CONCLUSION

✓ High resolution DEM can be generated using high resolution optical stereo data ALOS PRISM. But, there are bull eyes occurred which must be repaired.

✓ The accuracy of generated DEMs are depend on some factors, such as: number of input GCPs and spatial resolution of output DEM.

✓ DEM fusion can significantly reduce bull eyes in whole DEM image, and then improve the vertical accuracy of ALOS PRISM DEM.

✓ ALOS PRISM DEM is useful to fulfil the needs of detail DEM for many activities, such as: data correction process (image orthorectification and terrain correction) in carbon accounting system