Government of Central Kalimantan

Government of Indonesia

Government of the Netherlands

Master Plan for the Rehabilitation and Revitalisation of the Ex-Mega Rice Project Area in Central Kalimantan






QUICKSCAN EVALUATION OF USE OF LASER-ALTIMETRY DATA TO ASSESS PEAT LAND TOPOGRAPHY, CANOPY STRUCTURE AND SUBSIDENCE

Technical Review No. 4

JANUARY 2009

Euroconsult Mott MacDonald and Deltares | Delft Hydraulics
in association with
DHV, Wageningen UR, Witteveen+Bos, PT MLD and PT INDEC

Master Plan for the Rehabilitation and Rehabilitation of the Ex-Mega Rice Project Area in Central Kalimantan

Technical Review Number 4

Quickscan evaluation of use of laser-altimetry data to assess peat land topography, canopy structure and subsidence

Marnix van der Vat, Ronald Vernimmen and Al Hooijer

Delatres | Delft Hydraulics

Government of Indonesia

Royal Netherlands Embassy, Jakarta

Euroconsult Mott MacDonald / Deltares | Delft Hydraulics

in association with

DHV
Wageningen University & Research
Witteveen+Bos Indonesia
PT. MLD
PT. Indec

October 2008

Table of contents

List of tables

List of figures

List of abbreviations

ALS	Airborne Laser Scanning
ASCII	American Standard Code for Information Interchange
CKPP	Central Kalimantan Peat Project
DEM	Digital Elevation model (excluding vegetation, synonym of DTM)
DSM	Digital Surface Model (including vegetation)
DTM	Digital Terrain Model (excluding vegetation, synonym of DTM)
EMRP	Ex-Mega Rice Project
GIS	Geographical Information System
KC	Kalteng Consultants
LIDAR	Light Detection and Ranging
MRP	Mega Rice Project
MSL	Mean Sea Level
UNPAR	University of Palangkaraya

1 Introduction

1.1 Need for detailed and accurate elevation information in the EMRP area

Elevation data are crucial for assessing and designing rehabilitation and development strategies for the EMRP area, as topography controls the water flow that controls all other processes in this nearly flat deltaic area. Different uses require different levels of detail and accuracy:

1. For peatland hydrological models, it is most important that the general shape and gradients of the peat surface (defined as the bottom of interconnected hollows where these occur, as in intact forest) are accurately represented in elevation data, and that no 'closed depressions' occur (which at best would be inundated in models, at worst can destabilize the model). The vertical resolution and accuracy should be within 0.25 cm (at least within 0.5m); horizontal resolution can be larger than 25m for most applications.
2. For canal blocking design and associated local hydrological models in peatlands, it is necessary to know the exact shape of the canal side, especially location and dimensions of berms (elevated canal side where spoil was deposited) and smaller canals ('parits') to the back of it. A vertical resolution and accuracy within 0.25cm are needed; horizontal resolution should be very high to pick up these linear features: 1m or 2m (at least 3m).
3. For design of agricultural drainage/irrigation systems, the surface elevation relative to river levels should be known accurately to be able to predict drainability, flood risk and suitability for tidal irrigation). A vertical resolution and accuracy within 0.1m (at least within 0.25m) is required; horizontal resolution may be in the order of 10m.
4. For monitoring of subsidence and fire scars, as part of a carbon emission monitoring scheme, vertical resolution and accuracy should be sufficient to pick up changes of a few cm/year (subsidence) or about 0.2m/event (repeat fires). A vertical resolution and accuracy within 0.05m is required; horizontal resolution would need to be considered on a project basis but may be 100m or (at least within 250m) for areas with limited drainage density (and therefore limited topographic variation).
5. Several different vertical and horizontal resolution requirements apply to ecological and forestry applications of the data, including quantification of canopy structure and above-ground biomass.

When processing laser data, there is always a trade-off between detail and accuracy, as raw data are available at high resolution (several laser beams per m^2), but only a few percent of the laser beams hit the actual ground level as most are intercepted by the vegetation canopy. The larger the surface area represented in cells used in analyses, i.e. the lower the horizontal resolution, the higher the vertical resolution and accuracy.

Clearly, considering the different uses and requirements, processing and quality control of elevation data needs to be done in close co-operation with the end-users. Deltares | Delft Hydraulics, as a key user of the laser altimetry data in the EMRP area (and having experience in its use in other areas, including quality control of the new laser-based elevation model for the Netherlands), has evaluated date requirements and the potential to use laser data, in support of defining ways to best obtain elevation data in future projects.

1.2 Existing laser-altimetry (LIDAR) data for the EMRP area

In 2007, Kalteng Consultants has carried out an assignment for Wetlands International and UNPAR in the framework of the CKPP project titled "Airborne Laser Scanning monitoring of Ex-MRP area to archive high-resolution topographical Maps of Peatlands in Central Kalimantan, contract between Kalteng Consultants, UNPAR and Wetlands International". The aim of the assignment was to prepare a 3-dimensional Digital Elevation Model providing information for peat land hydrology models and for peat swamp forest biomass assessment. The ALS data have been acquired during a helicopter flight on August 7, 2007. Results in the form of raw point data and various processed forms including a Digital Surface Model and a Digital Elevation Model have been delivered between September and November 2007. A Technical Report has been delivered in November 2007 (Boehm, 2007).

Some of the data delivered have been used by Deltares | Delft Hydraulics in the framework of the CKPP and the EMRP Master Plan projects to prepare a DEM for the EMRP area. The result has been presented in the Master Plan (Euroconsult Mott MacDonald and Deltares | Delft Hydraulics, 2008) and a technical report (Hooijer et al, 2008a). The DEM forms one of the most important parts of the hydro-topographical database developed to serve as a basis for large scale physical rehabilitation of the EMRP area and more specifically for hydrological modelling.

Several problems occurred when trying to use the elevation data delivered by Kalteng Consultants:

- The elevations delivered were referenced to Mean Sea Level using an incorrect value for the elevation of the benchmark at Palangkaraya Airport (which is approximately 12m higher than actual elevation).
- The elevation presented in the Kalteng Consultants DEM included influence vegetation and therefore does not provide an accurate assessment of the surface elevation.
- A clear description of the steps undertaken in processing the raw data to prepare the DEM and DSM and other products is lacking.
- The format of the delivered data make analysis in standard GIS software such as ArcGIS difficult.
- The format and amount of raw data complicated analysis, combined with restraints on time available in the Master Plan project this prohibited use of the raw data.

Some of the laser-altimetry data have been used when preparing the Master Plan DEM. KC prepared for this a manual selection of 346 points with a supposedly limited influence of vegetation on the measured ground elevation.

The aim of the work described in this note has been to assess the possibility to use the raw data delivered to obtain information of surface elevation as a starting point for possible future use of laser-altimetry for the EMRP area. More specifically the possibility to use the data for the following purposes has been assessed:

1. Improvement of the DEM in general, especially focusing on the possibility to eliminate the influence of vegetation from the laser-altimetry data (Chapter 4);
2. Detailed assessment of topography around canals to support design of canal blocking structures (Chapter 5);
3. Detailed assessment of topography in zones where agriculture is to be developed/enhanced with the aim to support design of hydraulic infrastructure dealing with flooding, drainage, salinity and tidal irrigation (Chapter 6);
4. Assessment of vegetation height and structure to distinguish vegetation types (Chapter 7);
5. Assessment of subsidence by analysis of the difference between laser-altimetry data from different years.

As a starting point Chapter 2 describes the specifications of the data laser-altimetry data delivered.

2 Specifications of laser altimetry data

Table 1 presents the specifications as presented in the Technical Report (Boehm, 2007) together with specifications from a recent proposal (November 2008) for similar work in Block C apparently using the same LMS-Q560 Airborne Laser Scanner (Riegle scanner type 560 in Siegert, 2008).

Table 1 Specifications

Parameter	Technical Report (Boehm, 2007)	Proposal (Siegert, 2008)
Elevation-accuracy	+/- 0.15m	+/- 0.10m
Resolution in X and Y coordinates	+/- 0.15m	0.35m
Point-density	> 1 per m^2	8-10 per m^2
Number of ground return signals in forests	not defined	3-10%
Swath width	500m	400-500m

Specifications from the two different sources appear similar, except for the point density and the percentage of ground return signals in forests. These two parameters are crucial to obtain an accurate DEM excluding vegetation as proven by the problems encountered with the data delivered in 2007. In forests the most recent specification, if correct, would result in one surface elevation measurement per 1 to 4 m^2.

3 Point density

The raw data were delivered as X,Y,Z data pairs in ASCII format. The data from the whole flight where divided over 34 files, so-called spurs, each file containing approximately 10 million data pairs. Figure 1 presents the location of the spurs on a map.

Figure 1 Map with the location of the spurs

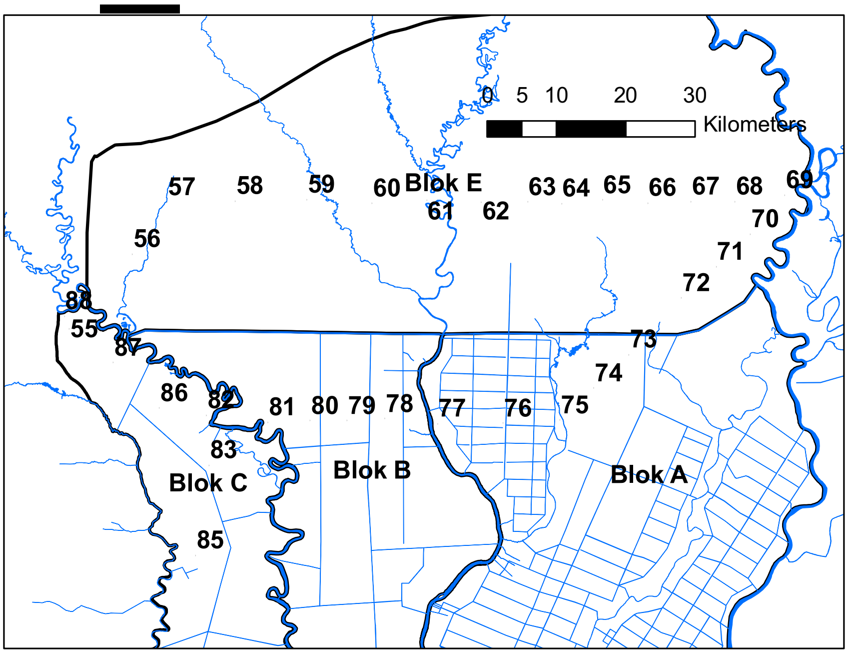


Figure 2 presents an assessment of the point density for spur 66, located in a forested area in Block E. To prepare this map, the raw data points were sampled into a 25 by 25m grid of 6km wide and 700m high. The low point density at the western edge of the map indicates the start of the spur. The low values at the northern and southern edge indicate the swath width.

Figure 2 Point density of spur 66 on a 25 by 25m grid over a swath width of 550m

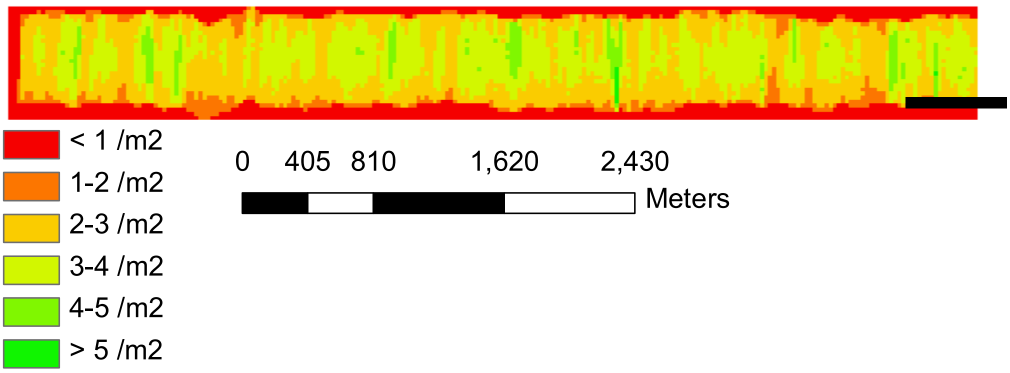


Figure 2 shows a large variation in point density. The average swath width is approximately 550m. The average point density in the centre of the swath is approximately 3 per m^2 and decreases towards the edges of the swat, leaving an average usable swath width of approximately 450m. The swath width falls within the ranges specified. The point density agrees with the specification of the Technical Report (Boehm, 2007), but is significantly lower than the 8-10 points per m^2 specified in the recent proposal (Siegert, 2008). It is not clear whether this increase reflects improved equipment, improved handling or an overestimation of the possible density.

4 Surface elevation and DEM

The main problem with laser-altimetry data is that the measured elevations in densely vegetated areas will mostly reflect the level of the top of the elevation instead of the surface. If it is possible to distinguish between points reflecting the vegetation elevation and points reflecting the surface elevation, the latter can be used to prepare a DEM and the difference of the two can be use to assess the vegetation structure. This chapter focuses on determination of surface elevation and a DEM; Chapter 7 presents a preliminary assessment of vegetation structure.

If we assume that the data have a percentage of ground return signals in forest as specified in the recent proposal (Siegert, 2008) of 3-10%, an overall point density of 3 per m2 (as we found for the raw data) results in an average of one surface elevation measurement per 3-10m^2. On a 10x10m grid this would results in 10-30 ground level measurements per grid cell.

The surface elevations can be retrieved from the raw data points by selecting for each cell one of the lowest values, assuming the other values represent measurements of the vegetation elevation. It is better not to use the absolute minimum value for each cell, since this would results in a systematic underestimation of the average surface elevation of the cell. With 3-10% penetration of the vegetation cover, the 3-10 percentile score of the values within a cell should provide a good estimation of the average surface elevation of the cell, provided that the cell is large enough to accurately calculate this percentile score. With an average point density of 3 per m^2, a grid cell size of 50m^2 should then provide good results.

A MS Visual Basic programme has been prepared by Deltares | Delft Hydraulics to transfer the raw point data as delivered by KC into grid data in ".asc" format for import into ArcGIS. To eliminate the disturbing impact of cells with fewer points, especially along the edges, cells with a point density of less than 1 per m^s were not included in the results. Furthermore, raw data points with an uncorrected elevation outside the range 0-50m were discarded. There appears to be no standard way to calculate percentiles. The method described by Dierickx (n.d.) follows the intuitive definition of percentiles and has been used here (although it deviates from the implementation in among others MS Excel).

As a first test a DEM is calculated from spur 66 on a 10x10m grid using for each grid cell the 3 percentile value. This should provide a smooth DEM if the percentage of ground return signals is within the range specified. Otherwise, a DEM with a large spatial variation is expected. The threshold of acceptable variation is related to the expected short distance surface variability and will be lower than 25cm. Spur 66 has been selected for this purpose because its location ensures a good forest cover and because of the absence of drainage. Hence it should represent a smooth and nearly horizontal (within a grid cell) ground surface.

Figure 3 presents the results of this first test clearly demonstrating that there is a large variation in surface level, especially along the edges, but also in the centre of the swat. Higher cells show that the 3 percentile value on a 10x10m grid is still influenced by measurements including vegetation. To eliminate vegetation measurements the cell size can be increased and/or the percentile can be decreased.

Figure 3 DEM from spur 66 on a 10x10m grid using for each cell the 3 percentile of the data points within the cell (with a 25cm interval in the legend)

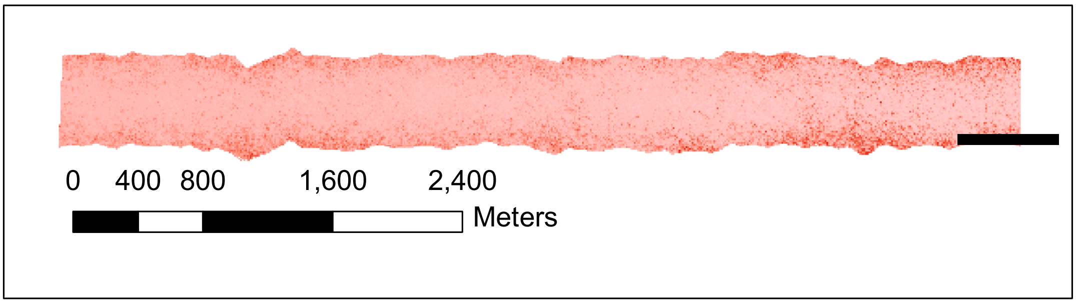


Figure 4 shows the result with the grid size increased to 25x25m and Figure 5 the result using the 0.1 percentile. Both results still show an unacceptable large variation in elevation between cells.

Figure 4 DEM from spur 66 on a 25x25m grid using for each cell the 3 percentile of the data points within the cell (with a 25cm interval in the legend)

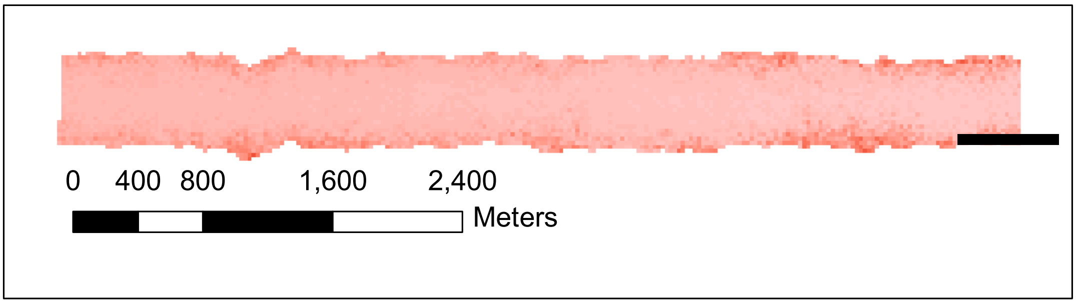


Figure 5 DEM from spur 66 on a 10x10m grid using for each cell the 0.1 percentile of the data points within the cell (with a 25cm interval in the legend)

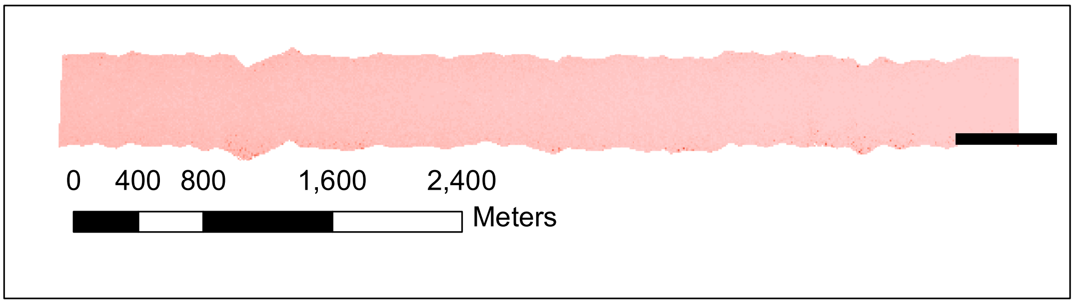
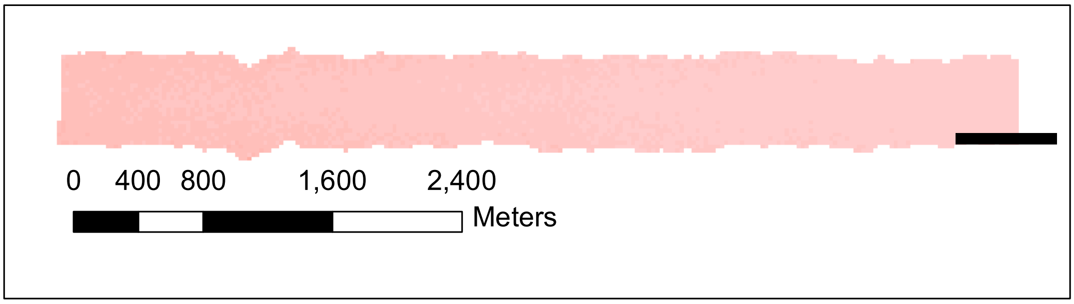


Figure 6 presents the results for a 25x25m grid using the 0.1 percentile. This result satisfies the criterion described above to be sure that the vegetation is excluded. Calculations have also been made with percentiles between 3 and 0.1. These results are not shown here, since they did not satisfy the criterion.

Figure 6 DEM from spur 66 on a 25x25m grid using for each cell the 0.1 percentile of the data points within the cell (with a 25cm interval in the legend)



From the above it can be concluded that the penetration of the vegetation cover in the current data is far less than the 3-10% percent from the recent proposal (Siegert, 2008). Based on the analysis presented above the penetration is not more than a few per mills. Furthermore, it appears from the presented results that penetration is less at the edges, which can be explained by the larger impact angle of the laser beam which increases the probability of interception by vegetation cover.

DEMs across Blocks A and B have been prepared using the settings found to eliminate the influence of vegetation from forest areas (e.g. a grid cell size of 25x25m and the 0.1 percentile score of values within the grid cell). The result for Block A is presented in Figure 7. Figure 8 presents the DEM from the Master Plan for the same area.

The transects across Block A from the laser-altimetry data and the Master plan DEM look quite comparable. Of course, the laser-altimetry data provide much more detail. Furthermore, the slope on the eastern side of the transect is steeper in the Master Plan DEM than in the laser-altimetry based DEM, resulting in a difference on the edge of 1.4 metres. With currently available it is hard to determine which DEM is more reliable. In general there is little reason to doubt the reliability of the laser-altimetry based data once the influence vegetation has been removed. The difference therefore is most likely explained by the inaccuracy of the Master Plan DEM. However, it could in theory also be that the laser-altimetry data in this area are disturbed by extremely dense vegetation cover.

Figure 7 DEM across Blocks A (spurs 75 to 77) on a 25x25m grid using for each cell the 0.1 percentile of the data points within the cell (elevation in meters above MSL)

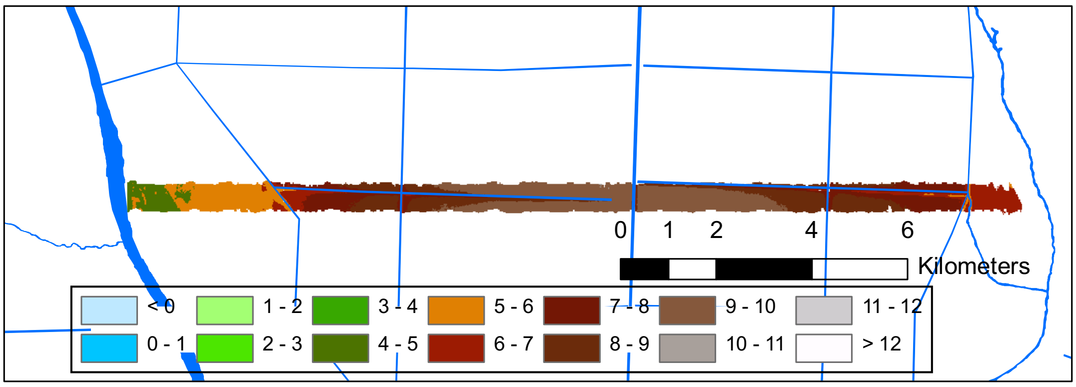
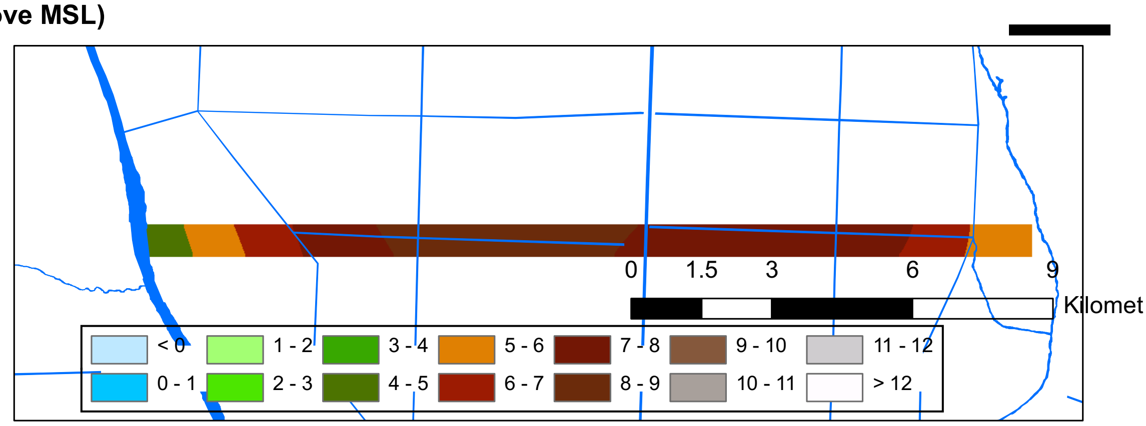


Figure 8 DEM across Blocks A based on the DEM from the Master Plan (elevation in meters above MSL)



KC has delivered a DEM on a 1x1m grid. It is not clear from the available documentation how this DEM has been prepared, especially regarding removal of influence of vegetation. Figure 9 presents the results for spurs 66 and 76 and Figure 10 and the differences with the DEM prepared from the laser-altimetry data on a 25x25m grid with a percentile value of 0.1. Figure 11 presents cross sections along spurs 66 and 76 showing both DEMs and a third DEM based on a 100x100m grid with a percentile value of 0.1.

The influence of the vegetation is clearly visible on the 1x1m DEM resulting in elevations up to 1.5 metres higher than those of the 100x100m grid. It is not clear how the 1x1m DEM is generated, but some sort of interpolation has apparently taken place and some influence of vegetation is included.

For spur 76 dominated by shrubland the difference between the 25x25m and the 100x100m DEMs in negligible. For densely forested spur 66 the coarser grid provides a more smooth and lower DEM, demonstrating that at 25x25m canopy penetration is not reached in each grid cell. With on average some 2000 points per 25x25m grid cells this means that penetration here is less than 0.05% and closer to 0.01%.

The average difference between KC DEM elevations and ground elevations as calculated by Deltares | Delft Hydraulics using KC raw data on a 100x100m is 0.3m for spur 66 and 0.5m for spur 76m. The spatial distribution of the difference is uniformly distributed over spur 66, while for spur 76 it is concentrated around the canals and especially in the western area covered by different types of shrubland according to the land use / land cover map (SarVision, 2008). The apparent and somewhat surprising higher difference in shrubland, compared to forest remains to be explained.

The cross section for spur 66 shows the overestimation by the 1x1m DEM of the elevation. Short range variation in this DEM is approximately 40cm, while in the 25x25m DEM this is 20cm and in the 100x100m DEM no shrot range variation remains. The cross section for spur 76 shows short range variation of up to 1 metre for the 1x1m DEM and a very smooth cross section for the 25x25m DEM and 100x100m DEMs. The latter are more in accordance with expectations, since peat forest has been cleared here, vegetation consists mostly of shrubs and the hummock-hollow micro-topography has disappeared. At 1700 and 4300m the cross section crosses canals. Here the 1x1m DEM shows a higher elevations along the canal, which identify the berms. This information is lost from the 25x25m and 100x100m DEMs.

Figure 9 DEM on a 1x1m grid as delivered by KC for spur 66 in Block E (above) and spur 76 in Block A (below) (with a 25 centimetre interval in the legend)

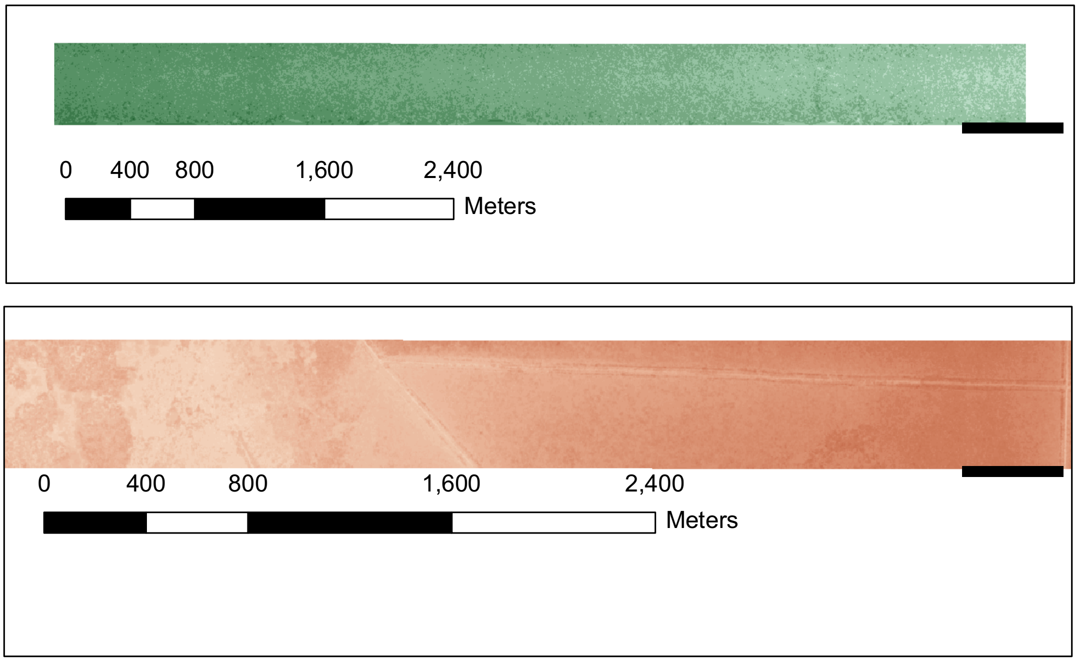


Figure 10 Difference between DEM prepared in this study (25x25m grid and 0.1 percentile, Figure 6) and DEM prepared by KC (1x1m grid, Figure 9) for spur 66 in Block E (above) and spur 76 in Block A (below)

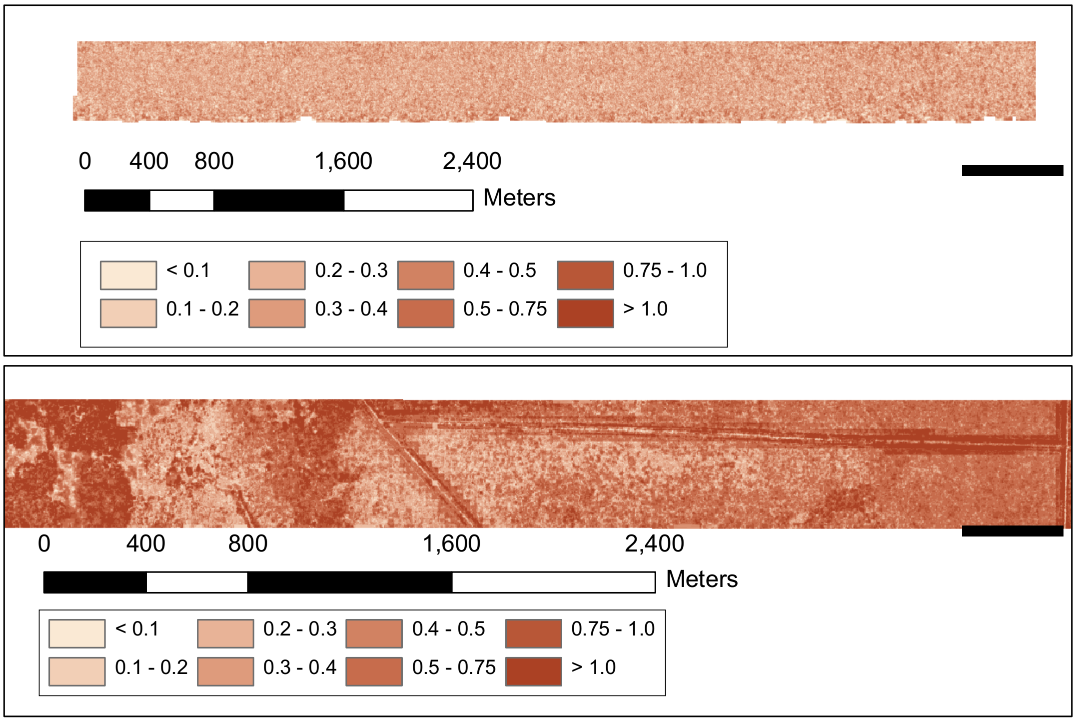
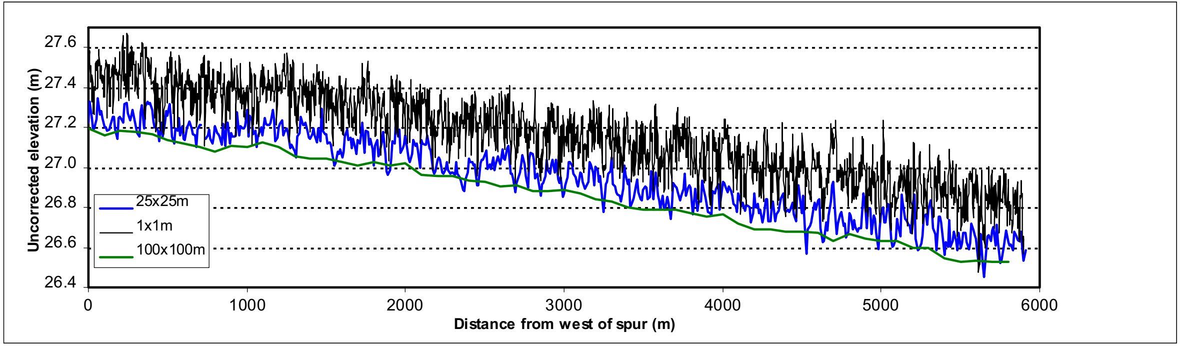
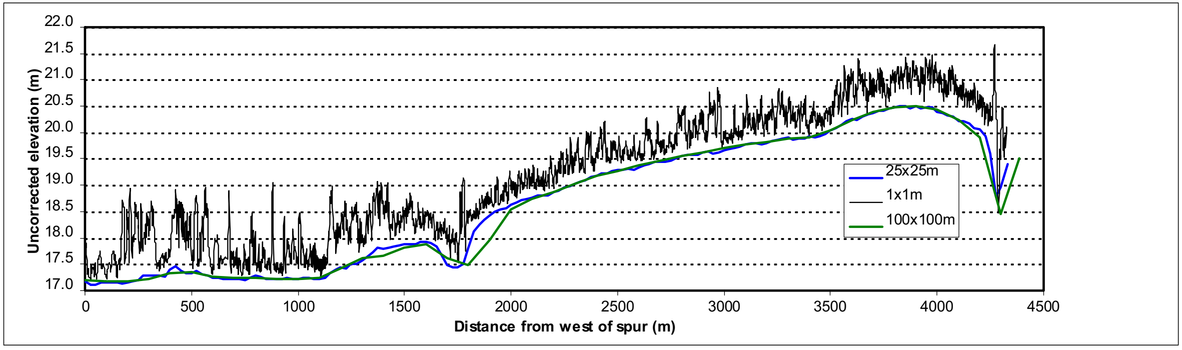


Figure 11 West to east cross sections in spur 66 in Block E (above) and in spur 76 in Block A (below) (NB: elevations are not corrected) showing KC DEM 1x1m, the 25x25m 0.1 percentile DEM and the 100x100m 0.1 percentile DEM





5 Canal cross sections

The 25x25m DEM presented above allows an assessment of the micro-topography away from drainage canals. Results of the Master Plan study suggest existence of depressions around the canals and “mini-domes” between the canals as a result of differentiated subsidence after construction of the drainage canals (Euroconsult Mott MacDonald and Deltares | Delft Hydraulics, 2008). Analysis of the higher gradients and small-scale features around canals (berms and ditches) will require a higher horizontal resolution than 25m.

Figure 12 presents the results for the western canal in Block A with a north – south orientation. For each row in the DEM a cross section was created extending 1km on each side of the canal. Since the grid size is 25x25m, a total of 40 cells are included in each cross section. The canal is located on an east – west oriented slope. Figure 13 presents similar graphs for the western canal in Block B.

In all cross sections shown, canals clearly have a profound effect on current topography. Depressions have formed along canals due to higher subsidence rates and/or fire frequency. Such depression zones typically extend a few hundred metres from canals, as was found in the MP project from analysis of 26 1km elevation transects perpendicular to canals (measured with ground surveys). In addition, the effect of the canal on surface flow from peat domes is apparent in Block B. The higher subsidence on the downstream side of the canal can be explained by the fact that in the original situation water from the upstream side of the canal flowed (overland and through the peat) through this area, but is now mostly intercepted by the canal. The impact on the upstream side of the canal is more moderate since flow from the upstream area is not intercepted. The subsidence in the first 500 metre to the west of the canal B could also be explained by fire. The cross section of the canal in Block A shows a more symmetrical pattern with subsidence decreasing with distance from the canal.

A new DEM has been prepared based on the raw data using a 2x2m grid and 0.1 percentile. This yields for each grid cell the minimum value of the data point (on average 12 per cell). This DEM should be able to provide information on small scale topography around the canals, such as the berms. However, due to the limited number of data points per cell, the results might include influence from vegetation. The resulting map for a 200x50m part around the western canal in Block Ais shown in Figure 14, while detailed cross sections for both canals from Figure 12 and Figure 13 are shown in Figure 15.

Figure 12 Cross section over the western canal in Block B (spur 80): median, maximum and minimum (above) and individual cross sections (below) (west on the left side of the graph)

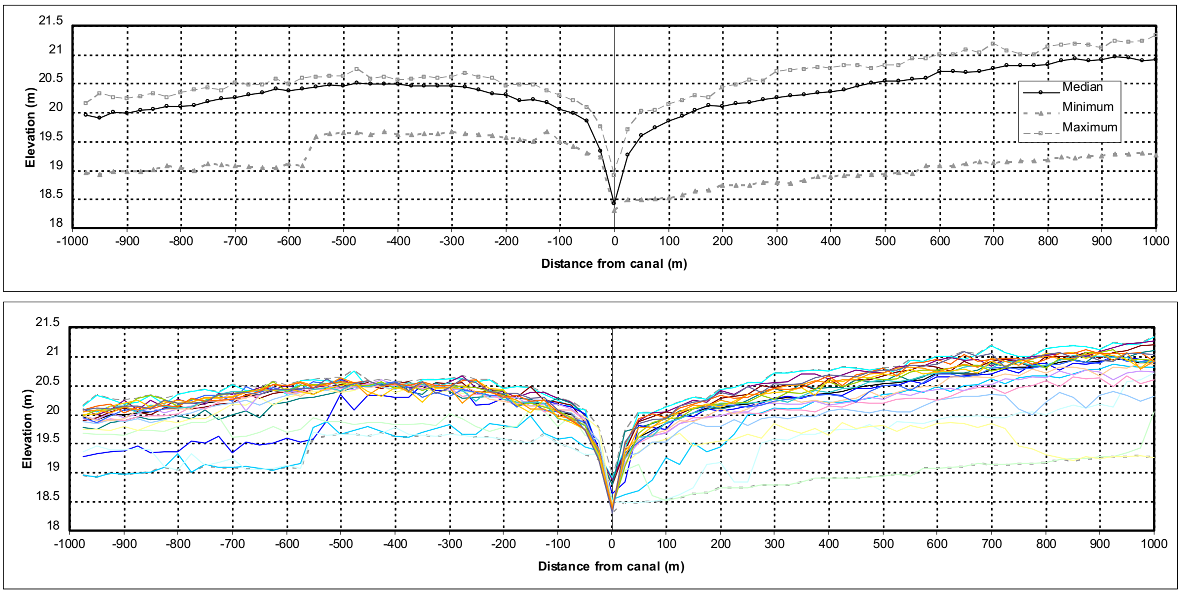


Figure 13 Cross section over the western canal in Block A (spur 76): median, maximum and minimum (above) and individual cross sections (below) (west on the left side of the graph)

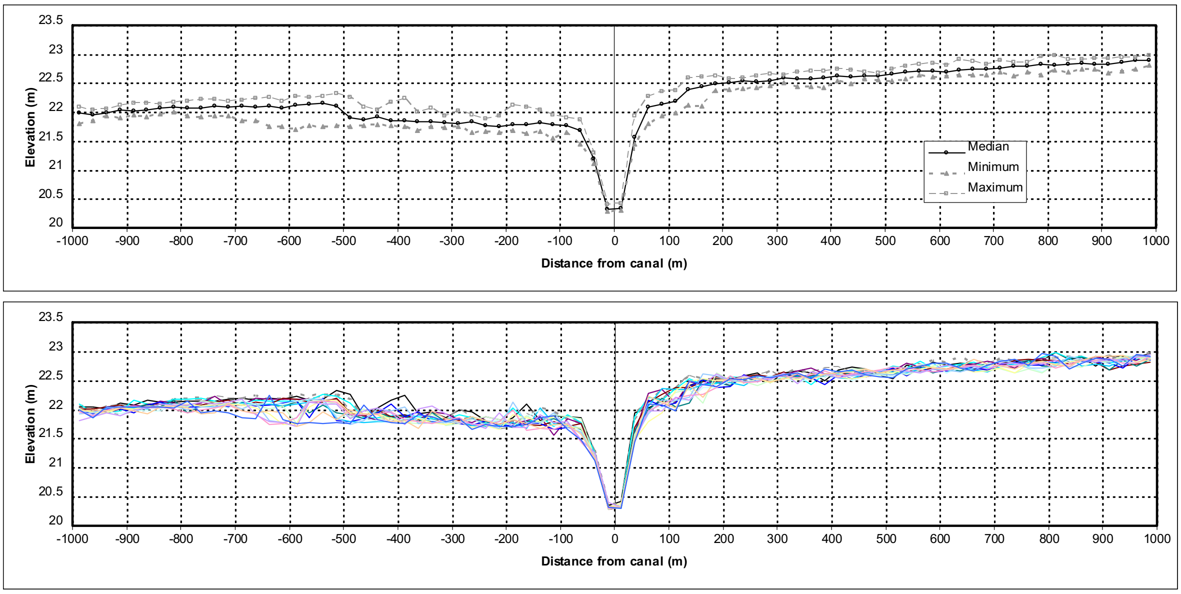


Figure 14 Map of the detailed 2x2m 0.1 percentile DEM around the western canal in Block A (spur 76) (height as uncorrected elevation above MSL)

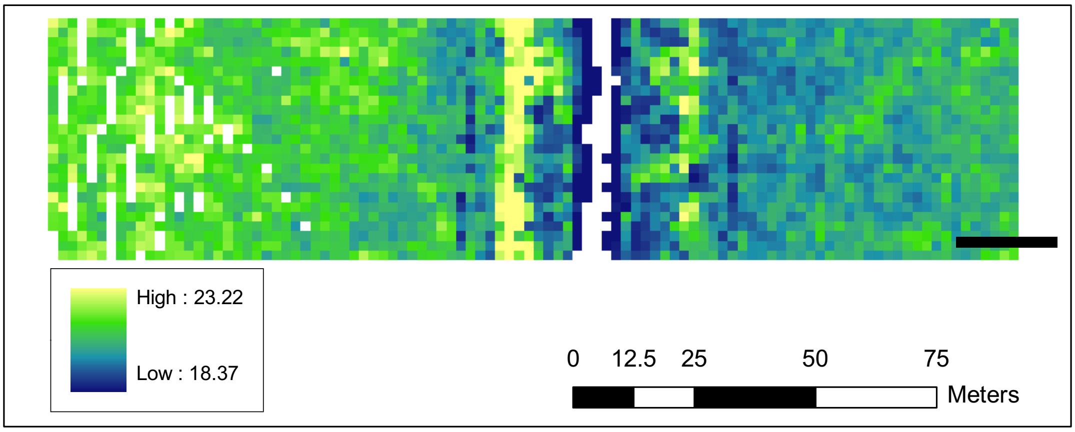
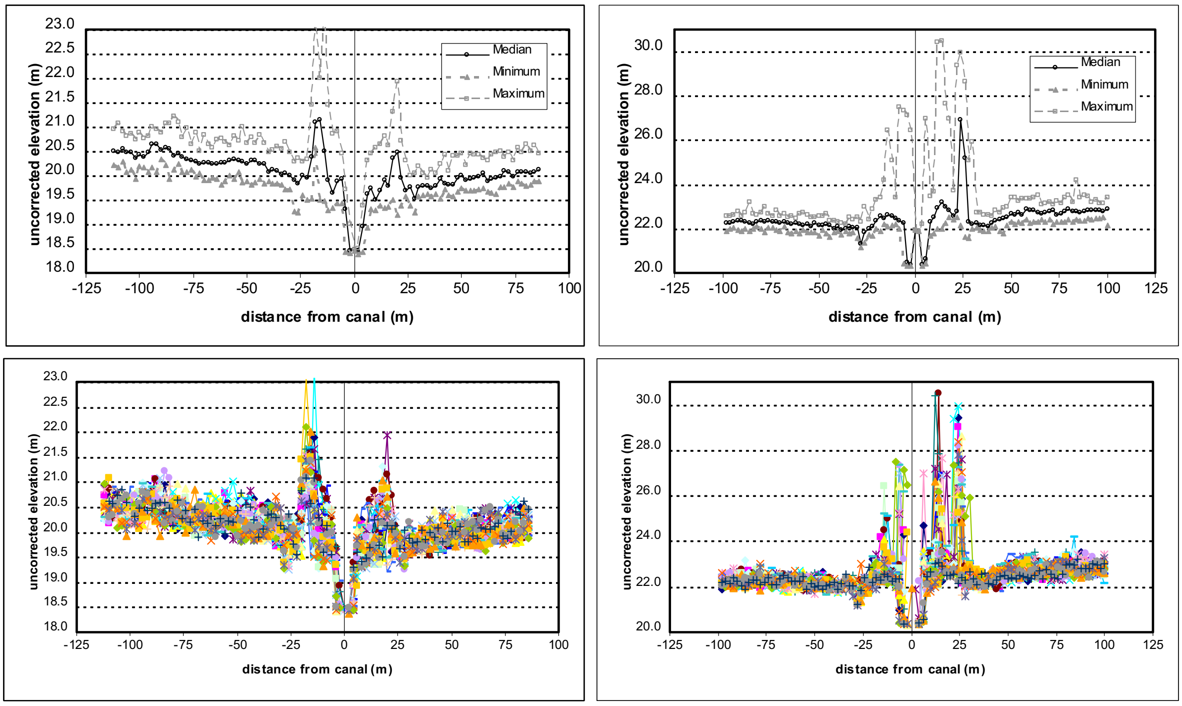


Figure 15 Cross section from the detailed 2x2m 0.1 percentile DEM around the western canal in Block A (spur 76,left) and the western canal in Block B (spur 79, right) (height as uncrorrected elevation above MSL)



The results of the 2x2m DEM clearly show the presence of the berms. The presence of small parallel canals with an a average width of 1m (“parit gendong”) is less clear. The graphs on the right in Figure 15 show berms of 8 metre heigh. this is impossible and most likely caused by vegetation on the berm which has not been filtered out, due to the limited number of data points in a grid cell at this fine resolution.

6 Use in agricultural areas

The Master Plan identifies the lack of accurate topographical information as a major limitation for planning of interventions in to improve agriculture in development zones. Major issues here include flooding, drainage, saline intrusion and tidal irrigation (Euroconsult Mott MacDonald and Deltares | Delft Hydraulics, 2008). For all of these issues an assessment of the relation between water and surface level (the hydro-topography) is required with an accuracy of 10-20cm. Laser-altimetry can potentially supply this information with the required spatial extent and horizontal and vertical resolution. No examples can be shown here, since the data available now do not cover agricultural areas.

7 Preliminary assessment of vegetation height

Obviously, the laser-altimetry data contain a lot of information regarding the vegetation height. It should be possible to determine for each grid cell an estimate of vegetation height distribution and relate this to vegetation type. Further cooperation with forest ecologists is required to investigate these possibilities. As part of the current investigation, a preliminary assessment of vegetation height has been prepared to demonstrate the possibilities of these data.

The median of point values within a grid cell can be expected to provide a reasonable indicator for average level of the top of the canopy, while the 99 percentile of the point values will provide an indication of the maximum canopy height. Figure 16 presents for Block B a cross section of these two canopy height indicators and the surface elevation. Clear distinctions are visible.

An indicator for vegetation height can now be assessed by subtracting the surface elevation from the median. The result of this procedure for Block B is presented in Figure 17. Figure 18 presents an extract from the land use / land cover map prepared by SarVision (2008) for the same area. There appears to be a very good correlation between the vegetation height indicator and the types of land use and land cover identified. The vegetation height indicator for the central part of swamp forest shows values continuously exceeding 10 metres. The western and eastern parts of the swamp forest show much more variation, which might indicate that these parts of the forest have a different vegetation structure naturally or are more degraded. The laser-altimetry data could provide in this way additional information on the type and/or state of the vegetation.

Figure 16 Cross section of Block B from west to east (spur 81 downto 77) showing on a 25x25m grid the soil surface elevation (0.1 percentile) and vegetation height (as 50 and 90 percentile)

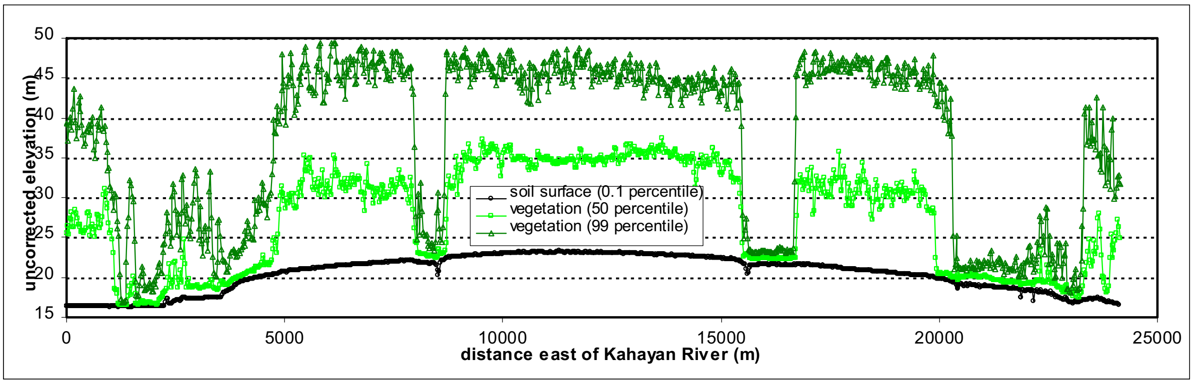


Figure 17 Vegetation height indicator for Block B (spurs 77 to 81)

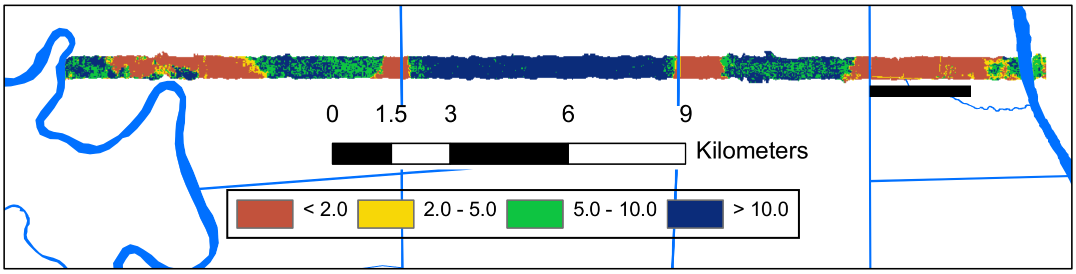
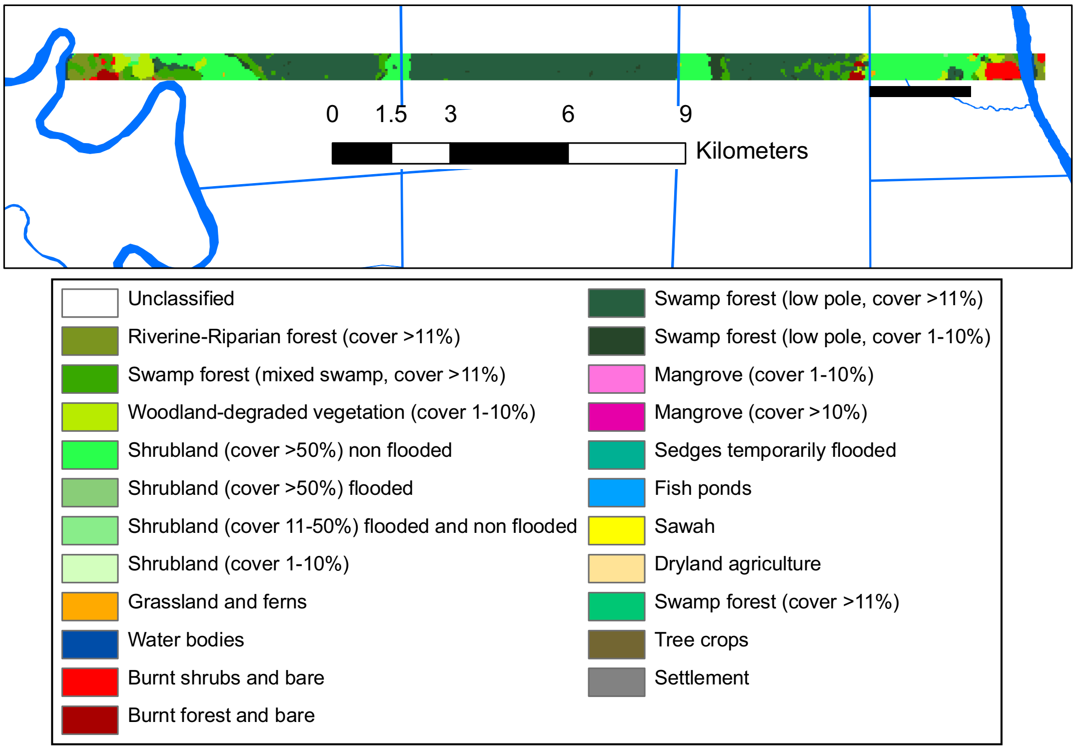


Figure 18 Land use/ land cover map as prepared by SarVision (SarVision, 2008)



8 Conclusions and recommendations

8.1 Conclusions

The evaluation presented in this report aims to assess the possibilities for further use of laser-altimetry data in the EMRP area rehabilitation and development projects, based on the data delivered in 2007 for two strokes in the northern part of the EMRP area (Boehm, 2007).

Specifications

The specifications of the data delivered have been compared with specifications from the Technical Report accompanying the data (Boehm, 2008) and the specifications included in a recent proposal for further work (Siegert, 2008).

The swath width averages 550m. On each side of the swath a strip of some 50 metres can not be used for most purposes due to the lower point density, resulting in a net swath width of 450m, which complies with the specifications in both the Technical Report and the recent proposal.

Point density ranges between 2 and 10 points per m^2 with an average of 3 point per m^2 and lower values towards the edges of the swat. This complies with the density specified in the technical report of more than 1 point per 1 m^2, but falls short of the specification in the recent proposal of 8-10 points per m^2. It is unclear how this increase in point density will be obtained, since it appears that the same scanner will be used.

Surface elevation and DEM

To assess surface elevation from laser-altimetry data, the influence of vegetation has to be removed from the raw data. To accomplish this, the raw data have been sampled into a regular raster with different grid cell sizes using different percentiles of the values within each grid cell. The results for a densely forested spur show that applying a grid cell size of 100x100m, combined with the 0.1 percentile point selection, allows near-complete elimination of vegetation effects and provides surface elevation data.

This means that in dense forest not more than a few per ten thousand (0.01%) of the signals penetrate the vegetation cover to measure the surface elevation. This is far below the 3-10% as specified in the recent proposal for further work (Siegert, 2008).

The 1x1m DEM delivered by KC provides a good first indication of the topography. However, comparison with the 25x25m and 100x100m DEMs produced during this investigation, shows a systematic overestimation of the elevation by the 1x1m DEM of on average 0.3 to 0.5m. This does not comply with the specified vertical resolution of +/- 0.15m (Boehm, 2007).

It can be concluded that the available raw data contain enough information on surface elevation to prepare a DEM with grid cell sizes of 25x25m or 100x100m for dense forest. From the short range variation it has been deducted that the elevation accuracy is approximately +/- 10cm. For areas with less vegetation cover than dense forest or shrub/ferns, and thereby a higher penetration of laser beams, the data contain enough information to obtain elevation information on a higher horizontal resolution. This can theoretically be up to 1x1m in the absence of vegetation, but it is probably realistic to say that the lowest horizontal resolution achievable is somewhere between 2x2m and 5x5m.

It is understood that improved smoothing and re-sampling techniques are suggested to obtain laser-altymetry based DEMs with resolutions of 1*1m. It should be noted, however, that such techniques eliminate the linear landscape features that require high-resolution data in the first place.

Canal cross sections
The 25x25m DEM as derived in this investigation from the raw data provides reliable information on the topography around the canals to analyse the “mini-dome” topography resulting from differential subsidence around the canals.

More detailed information, such as the location and height of the berms along the canals (consisting of spoil from canal digging) and the small canals parallel to the main canal (“parit gendong”)is not present in the 25x25m DEM due its spatial resolution. A new 2x2m DEM (prepared in the same way as the 25x25m DEM with a percentile value of 0.1) shows the location and height of the berms. However, at this scale influence of vegetation cannot be excluded.

Agricultural development
No examples of application of the laser-altimetry data for agricultural areas could be investigated, since no such areas are present in the available data. However, from the available data it is expected that application of laser-altimetry data with similar specification can be used to construct a DEM satisfying the requirements for spatial and vertical resolution to support design of the hydraulic lay-out and infrastructure to deal with flooding, drainage, saline intrusion and tidal irrigation.

Vegetation height and structure
A first assessment of vegetation shows a clear correlation with the land use and land cover types distinguished by SarVision (2008). Additional information on the type and/or state of the vegetation seems to be present in the data, but has not been further analysed at this moment.

Subsidence monitoring
The rate of subsidence in peat land areas as the EMRP area declines with the years passing since drainage started. Actual subsidence rates are estimated to be in the order of 1-3 centimetres per year (Hooijer et al, 2008b). With the currently specified and found vertical resolutions (an accuracy of approximately +/- 10cm), subsidence monitoring is therefore only feasible on a time scale of several decades, not years. For subsidence monitoring larger grid cell sizes are feasible and maybe even desirable.

General
Laser-altimetry in theory provides an opportunity to obtain elevation data for the EMRP area with a better coverage and better vertical resolution and accuracy than obtained so far by ground based measurements. This can be of great value for future projects in the area focusing on both peat land conservation and agricultural development. However, this theoretical value has so far not translated in practical applicability of the data provided by KC, because A) real data requirements (resolution and accuracy) have been insufficiently understood by KC, B) processing of data to obtain real ground depths has been insufficiently thorough yielding inaccurate results, C) unrealistic expectations have been raised on resolution and accuracy D) insufficient documentation results have been insufficiently documented.

8.2 Recommendations

The most important conclusions for the process of preparation of the laser-altimetry data and their use in the Master Plan project are:

- It is strongly recommended that end-users (hydrologists, ecologists, design engineers and carbon emission experts) participate in the definition of Terms of Reference for further acquisition of laser-altimetry data, in data processing and in the quality control of results delivered.
- As different end-users have very different requirements to start with (at least 5 types were identified in this quickscan; there will be more), in terms of resolution, accuracy and focus locations, and as these requirements will evolve during processing and evaluation of each dataset, it is strongly recommended that laser-altimetry data processing is done in the project office by specialists who work as consultants, with the other project consultants and throughout the project. It appears to be common in remote-sensing projects to collect and process data as a one-off activity, paid on lump-sum basis. This situation is responsible for the limited use that can be made of such data, which too often do not meet the real user requirements.
- End-users should be included from the start in the preparation of data collection and in the processing of results.
- More adequate documentation of the data availability, the processing undertaken and the accuracy achieved is essential.
- Penetration of the canopy of peat swamp forests by laser-altimetry is extremely limited (below 0.05%). Therefore, point density should be maximized for these areas, when obtaining new data. For the currently used Riegle 560 scanner can provide up to 20 points per m^2 if flown sufficiently slow. for other areas a further analysis of canopy penetration is required to assess the required point density.
- Further processing and evaluation of the Lidar data currently available for the EMRP area is recommended:,
    - To assess the possibility to prepare more detailed information on the micro-topography around the canals.
    - To assess the possibility to obtain information on vegetation height and structure.

9 References

Boehm, H.-D.V, (2007) Airborne Laser Scanning monitoring of Ex-MRP area to archive high-resolution topographical Maps of Peatlands in Central Kalimantan, contract between Kalteng Consultants, UNPAR and Wetlands International. Technical Report Kalteng Consultants.

Dierickx, T. (n.d.) Computing Percentiles - Are Your Values Correct? Available on Internet at http://www.data-for-all.com/documents/computing-percentiles.pdf, accessed on January 15, 2009.

Euroconsult Mott MacDonald and Deltares | Delft Hydraulics in association with DHV, Wageningen UR, Witteveen+Bos, PT MLD and PT INDEC (2008) Master Plan for the Rehabilitation and Revitalisation of the Ex-Mega Rice Project Area in Central Kalimantan. A Joint Initiative of the Governments of Indonesia and the Netherlands. Main Synthesis Report October 2008.

Hooijer, A., M. van der Vat, R. Vernimmen, JJ. Brinkman and F. Zijl (2008a) Technical Report: Hydrology of the EMRP area, and water management implications for peatlands. Master Plan for the Conservation and Development of the Ex-Mega Rice Project Area in Central Kalimantan. Cluster 3 Hydrology and Peatland Water Management. Delft Hydraulics.

Hooijer, A., M. Haasnoot, M. van der Vat and R. Vernimmen (2008b) Technical Report: Peatland subsidence scenarios for the EMRP area. Master Plan for the Conservation and Development of the Ex-Mega Rice Project Area in Central Kalimantan. Cluster 3 Hydrology and Peatland Water Management. Delft Hydraulics with a contribution from H. Wösten (WUR).

SarVision (2008**)** Revised Land Use / Cover Map of the Ex-Mega Rice Project Area and Sebangau,Central Kalimantan.

Siegert, F. (2008) Monitoring of peat carbon stock in Central Kalimantan using highres LIDAR data and aerial imagery. RSS Remote Sensing Solutions GmbH.

Bappenas
Secretariat
Inpres 2/2007

Jl. Taman Suropati
No.2,
Jakarta 10310

www.bappenas.go.id

Bappeda Central Kalimantan
Secretariat Inpres
2/2007

Jl. Diponegoro 60,
Palangka Raya
73111,
Kalimantan Tengah

www.kalteng.go.id

Royal Netherlands Embassy

Jl. H.R. Rasuna
Said Kav. S-3,
Kuningan
Jakarta 12950

indonesia.nlembassy.org

Euroconsult Mott MacDonald

S. Widjojo Centre, lt. 3
Jl. Sudirman Kav. 71
Jakarta 12190

www.euroconsult.mottmac.com

Deltares | Delft Hydraulics

P.O. Box 177
2600 MH Delft
The Netherlands

www.wldelft.nl