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In cooperation with

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An improved spatial flooding model of the Inner Niger Delta

A&W-report 2529

Commissioned by

Wetlands International

An improved spatial flooding model of the Inner Niger Delta - Final technical report

A&W-rapport 2529

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Contents

1 Introduction

BAMGIRE-project

The management of water resources in a land-locked country as Mali is complex and involves a multitude of stakeholders and interest. Through the program of PCA-GIRE (2015-2020), the embassies of Sweden and The Netherlands are supporting and coaching the process of implementation of Integrated Water Resources Management in the Upper Niger Basin. The overarching goal of this program is to: Strengthen the implementation of IWRM at the local, national and international levels by supporting Malian authorities and other stakeholders involved in the implementation of the national IWRM policy.

The BAMGIRE project (2015-2019), led by Wetlands International Mali, is part of the larger PCA-GIRE program. BAMGIRE encompasses the support of the political process and provides the science-based background and content to the process. The project of BAMGIRE is set up in different modules, arranged in a logical framework. Amongst others, this refers to the hydrological modelling of the system including a detailed spatial flooding model of the Inner Niger Delta (IND), the setup of an Observatory for the Upper Basin, an ecosystem services mapping of the IND, an ecological hotspot analysis of the Upper Niger Basin, and a decision support system for IWRM in the basin (Figure 1.1).

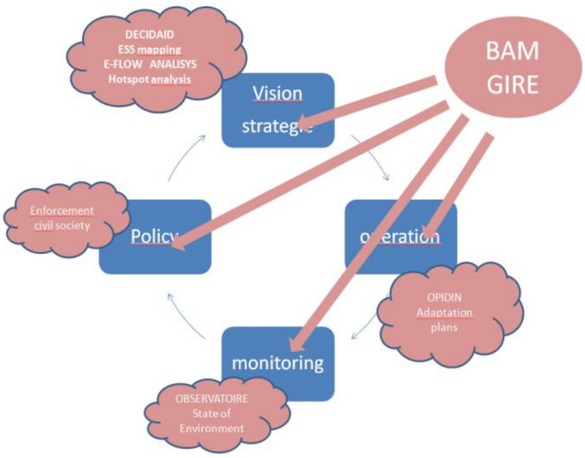


Figure 1.1 Simplified structure of the BAMGIRE project, projected on a general management and policy cycle

The overall goal of the BAMGIRE project (2015-2019) is *"A living Inner Niger Delta, where livelihoods and biodiversity are secured in a changing environment"*. The specific Project Objective is that "Government, decentralized institutions and community actions sustain the flooding regime and natural resources of the Inner Niger Delta so that livelihoods, biodiversity and the economy can adapt to a changing environment".

Spatial Flooding model: heart of BAMGIRE

The future of the flood-depending ecosystem and economy of the Inner Niger Delta (IND) is one of the focal issues in the near-future developments and the IWRM-process in Mali. Upstream interventions, resulting in a decreased river flow, impact directly on the hydrology (and ecosystem) and indirectly on the economy inside and around the IND. The economy of the IND is of national significance since the IND sustains the livelihoods of 3 mln people, and is a driver of the rural economy of Mali as far as fish production and livestock are considered. Moreover, the IND is one of the largest floodplain systems in Africa with high international ecological values.

The flooding of the IND is depending on the river inflow at the entrance of the Delta at Ké Macina (Niger river) and Sofara (Bani river). This river discharge on its turn depends on the upstream water management, in particular the impact of the future extension of the Office du Niger, the building of the Moussako (former Fomi) dam and other interventions. The quantification of the impact of upstream water management on the IND and its natural resources and values, is elaborated in *Niger, a lifeline* (Zwarts et al. 2005). In this work the relationships between annual flooding and production of natural resources are quantified in detail.

The reliability of the above mentioned quantifications is depending on a proper flooding model. Since 2005 (*Niger, a lifeline*) the knowledge about modelling and the amount and quality of data have been improved, making it possible to improve the existing flooding model and make it much more detailed (Chapter 2). This is not only important for impact assessments (IWRM-process, PAHA etc.) but also for the communities in the Delta this is highly relevant. The spatial flooding model is also used for the flood-forecast tool OPIDIN (www.opidin.org), which predicts the height of the flood and inundation extent in the flooding season.

This technical report describes the process of development, the technical approach and methods, and the final results and products. For more information on the hydrological background we refer to Zwarts et al. (2005), and the websites www.opidin.org and www.onisdin.org which offer much detailed hydrological information (but are at the moment of writing of the report – January 2019 – partly still under construction.

Partners

The flooding model is based on water level data provided by the Direction National Hydraulique (DNH) of Mali. The DNH offers a valuable database for the water management of Mali. This database is continuously refreshed through daily measurements of water levels. For more information see www.onisdin.org.

The water level data are used in combination with satellite images (free to download, see Chapter 2-3). The analyses (data processing, python scripts and algorithms, analyses of satellite images) is carried out by Altenburg & Wymenga and the Danube Delta Institute, who did this work also in 2001-2005, which guarantees an efficient work process. Advice and support is given by Wetlands International (Ede, Mali) and Python United (it specialist, technical advice).

2 Improving the existing flooding model (2005)

The Niger, a lifeline / Le Niger, une artère vitale (p. 43- 67) describes in detail how the flooding of the Inner Niger Delta can be quantified using satellite images from different dates and thus from different water levels. Flooding determines life in the Inner Niger Delta and each study of the socio-economic and biological functioning of the area should be based on a sound description of the flooding and how it varies from year to year. Hence also in The Niger, a lifeline / Le Niger, *une artère vitale* (Zwart et al. 2005) the flooding model is of paramount significance.

The flooding model has been tested extensively in the field since 2004 and appeared to be extremely accurate. The model has been used to make an Atlas (Zwarts & Hoekema 2013) and the same data are integrated within the flood viewer of OPIDIN (www.opidin.org).

The project BAMGIRE allows us to further substantiate and actualize the data relevant regarding the socio-economic and biological functioning of the Inner Niger Delta. That made it worthwhile to improve the existing flooding model. We aimed for five substantial improvements:

1. **Extension of the area.** The existing model (2005) is restricted to the central part of the area, thus without the floodplains in the SW (a few along the Niger near Macina but more along the Bani SW of Sofara) and the floodplains and temporary lakes in the NE (east of Diré).
2. **Larger data set**. The existing model is based on a limited set of satellite images, in total from 24 days, 11 for incoming and 13 for receding water.
3. **Higher flood levels.** The existing model is based on 24 satellite images from the period 1984-2003, with relatively many days with a low flood and only one day with a relatively high flood.
4. **More hydro-stations**. The existing model is based on the water level measured in Akka and is accurate for the central part of the Inner Niger Delta, but is less reliable for the southern and northern part of the Delta. The main problem is that the water level declines already in the southern Delta when it still goes up in the northern delta. The new flooding model must take this into account.
5. **Separate rain and river water.** The existing model distinguishes water from land. However, not all areas being covered by water are flooded by the river. Isolated depressions may be filled by rain water. The existing model used a simple mask to distinguish “flooding by the river” from ‘flooding due to rain” depending on whether there was a connection with the river, or not. This differentiation may be improved, but it has to be checked whether this can be implemented in the model.

In this technical report the existing flooding model is indicated as the existing or ‘old model’ and the model we are working on as the ‘new model’. In this Chapter we elaborate on the possible improvements and the approach which was taken. In Chapter 3 the technical part of the methods are described shortly.

2.1 How to improve the existing model: 1. Extension of the area

The old model was based on Landsat images paths and rows 197-49 and 197-50 (Fig. 2.1). The new model is based on a set of images from the same path (197) but from four rows (48-51). In this way, the flooding of Lac Faquibine in the north and the floodplains along the Bani in

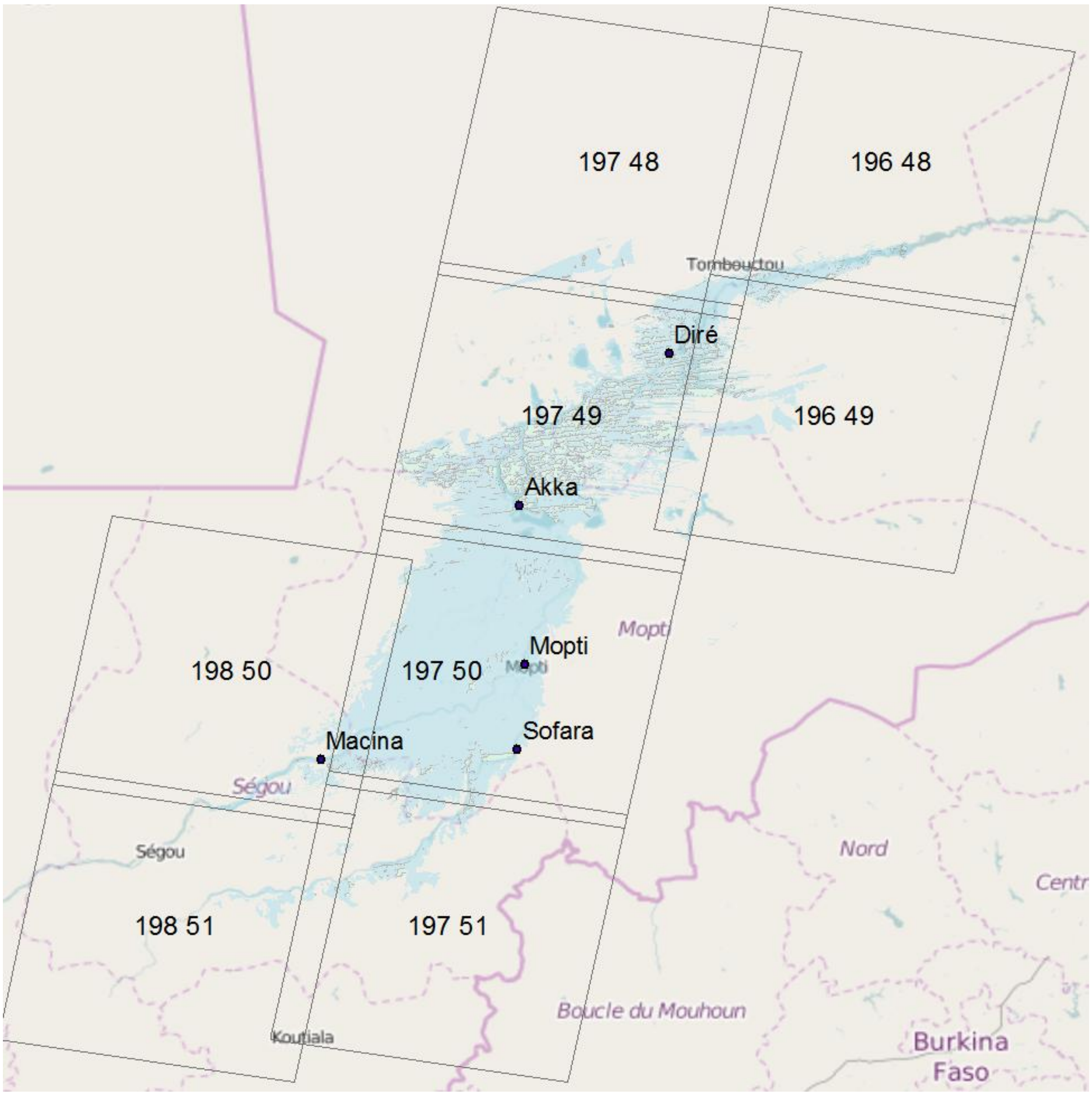


Figure 2.1 The Landsat images needed to make a complete flooding model of the Inner Niger Delta. The images are indicated with a path number (196-198) and a row number (48-51).

the south are included in the new flooding model. Therefore, in the new model we use four instead of two images to visualise the flooding. We still need, however, also images from path 198 to cover the floodplains in the SW (row 50 and 51) and from path 196 to cover the floodplains along the Niger downstream of Tombouctou and the filling of the lakes east of Dire (row 48 and row 49).

2.2 How to improve the existing model: 2. Larger data set

The old model was based on Landsat images we had to buy (2001-2005), which explains why the old model was based on a small set of images. For the Inner Niger Delta, thousands of Landsat images are now freely available. Although they can now be downloaded for free, we made a strict selection from this large data set:

1. No satellite images from Landsat 7 are used (being difficult to handle due to “stripes”); hence most images between 1999 (when Landsat 7 was launched) and 2013 (when Landsat 8 became available) could not be used;
2. No satellite images with clouds (in case of high cloud cover, images are not usable); hence we used limited data from the raining season (July-September);
3. No satellite images were used if other images from the Delta along the same path from the same day were not available (usually due to clouds);
4. No satellite images were used after the water starts to recede in the northern Delta (flooding season ends with receding flood in northern delta); hence no data from December-May.

After applying these restrictions, Landsat images were available from 95 different days for path 196, 108 days from for path 197 and 92 days for path 198. The full list is given as appendix (Appendix I).

Despite careful selection of images with very low or zero cloudcover percentage, the dataset for the 43 cm waterlevel (measured in Akka) still contains some cirrus clouds for a small area situated to the west of Konna (Fig. 2.2). Therefore, the new flooding model is not reliable for that specific area. In 2019, the image with cirrus clouds will be removed from the dataset.

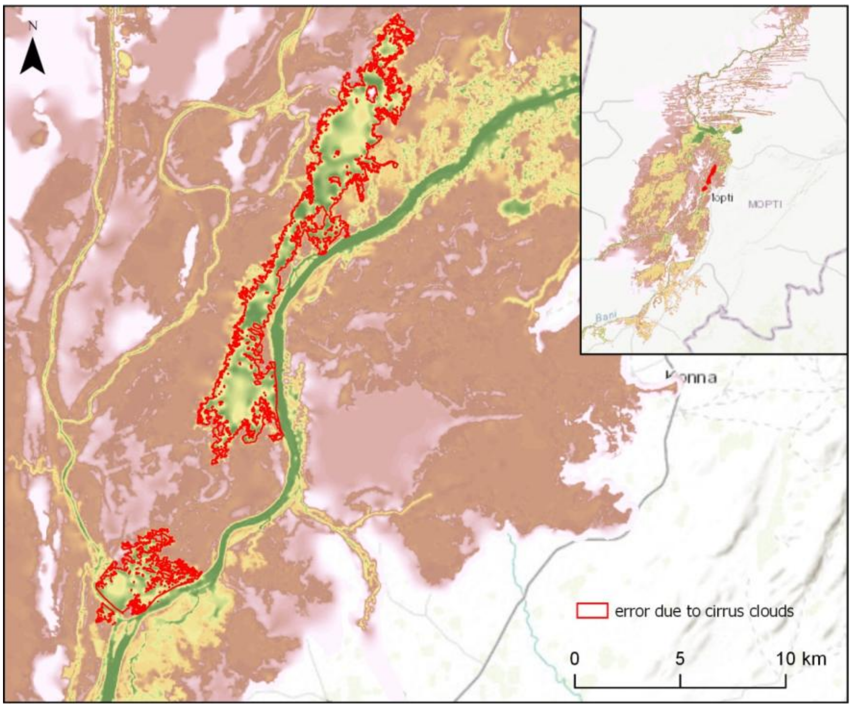


Figure 2.2 Detail of the new flooding model showing the area near Konna which contains error due to presence of cirrus clouds (cloud boundaries are shown in red).

The appendix gives the water level measured in the five major hydrological stations: Macina, Sofara, Mopti, Akka and Diré (see Fig. 2.1). For the interpretation of the data it is important to know whether the water has been higher than the observed level during the period before the selected day (to know whether the water is coming in or receding). The full set of daily water levels (data of DNH) was checked to see whether the water has started to decline already at the station; this is indicated in the last 5 columns of the table (see Appendix I). Images were not selected if the water has started to decline already in Diré.

From the large date set given in the appendix, another selection was made to have sufficient data for the different water levels. For instance, images with a water level between 200 and 400 cm in Akka were scarce; hence all days were selected. In contrast, there were many images with a lower water level; hence only a fraction of these images, usually only the most recent ones, was selected. The images used in the new model are indicated with a yellow colour in the table (see appendix). The new model for *incoming* water is be based on 56 satellite images (instead of 24 in the old model).

2.3 How to improve the existing model: 3. Higher flood levels

The old model was not able to produce an accurate prediction of the flooding at a high flood level, since these data were not available when the analysis was done. The highest flood in the old model was 607 cm in Mopti on 29 October 2000. The new model uses higher flood levels up to 620 cm in Akka (October 2015). This means that it is still not possible to indicate the actual flooding at the highest water levels (which have been one meter higher; the highest water level ever observed since 1922 is 739 cm in 1924) (Fig. 2.3).

While doing the first analyses in August 2016, it became evident that 2016 would be the first very high flood since the 1970s. The flood level in 2016 became indeed very high, although not as high as foreseen in early August. Nevertheless, it was worthwhile to wait for the recent data, since we got several satellite images with a high flood level, with as maximum a water level of 657 cm in Mopti, being 50 cm higher than the maximum in the old model. That is an important improvement of the old model. This improvement is not only relevant in relation to higher water levels at a higher flood, but also serves as a detailed DEM model for the area (see Chapter 4. Results).

What was not foreseen while finishing the model in the end of 2018, that in the flooding season of 2018 the highest flood level since 1969 was reached: 670 cm in Mopti and 540 cm in Akka. This is much higher than in 2016 (13 cm) and will again be very important for finalising the model. This will be done in 2019, as we first have to select cloudless images for this period. It will result in a much more detailed DEM model (based on water levels) for a large area, including the higher parts of the floodplain.

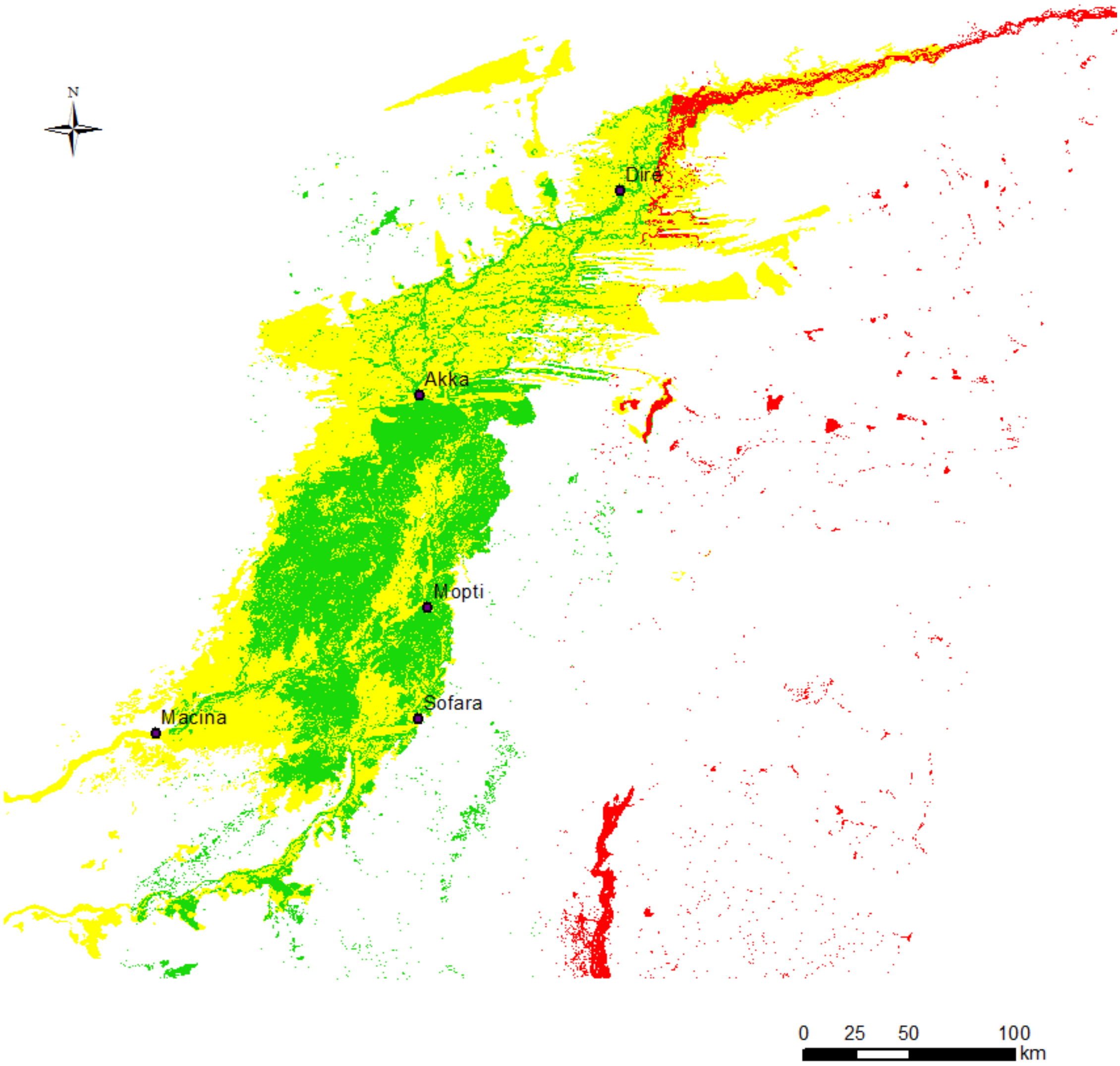


Figure 2.3 The flooded area in the Inner Niger Delta as far as visible on path 197 (31 October 2015; water level in Mopti: 618 cm green) and on path 196 (24 October 2015; red; water level in Mopti: 622 cm); the floodplains visible on path 198 are not shown.

2.4 How to improve the existing model: 4. More hydro stations

The analysis so far was done in several steps:

1. Satellite images from the same day and the same path were merged.
2. The merged satellite images were converted to water maps.
3. Each water pixel got the water level of the five hydro-stations.
4. The water maps were arranged according to the water level measured in the five different hydro stations.

2.5 How to improve the existing model: 5. Separate rain and river water

The flooding of the Inner Niger Delta is due to the increase of the flow of the Niger and Bani Rivers. The impact of local rain on flooding is limited, but not insignificant. The old model used a mask to ignore all isolated, shallow water lakes filled by rain water (visible as isolated dots in Fig. 2.3). It is possible to distinguish, separately for each date, water bodies that are connected to the river system and that are separated from it. We are especially interested in the northern lakes in the periphery of the Delta of which it is not yet clear to what degree their hydrological conditions depend on the local rainfall and/or the flood level.

Although the unconnected and connected water bodies were calculated for several water levels, this was not (yet) included into the current model, as this focuses on the incoming water and the water being inundated at the particular maximum water level (independent of the wave of the flood).

Figures 2.5 & 2.6 (pages 9-10) show for different dates and with different water levels (2015) the difference between isolated and connected water bodies. This analyses were done for a series of images. In Figure 2.4. (below) it can be seen, that water bodies which are, or become, isolated cover a varying portion of the wet parts of the delta: about 15-20% during the height of the flood, and (logically) amounting to 50% when flood is receding.

In the current new model (December 2018) it was decided not to distinguish further between isolated and connected water bodies, as this made the further analysis and interpolation much more complex. This is however a future element for improvement.

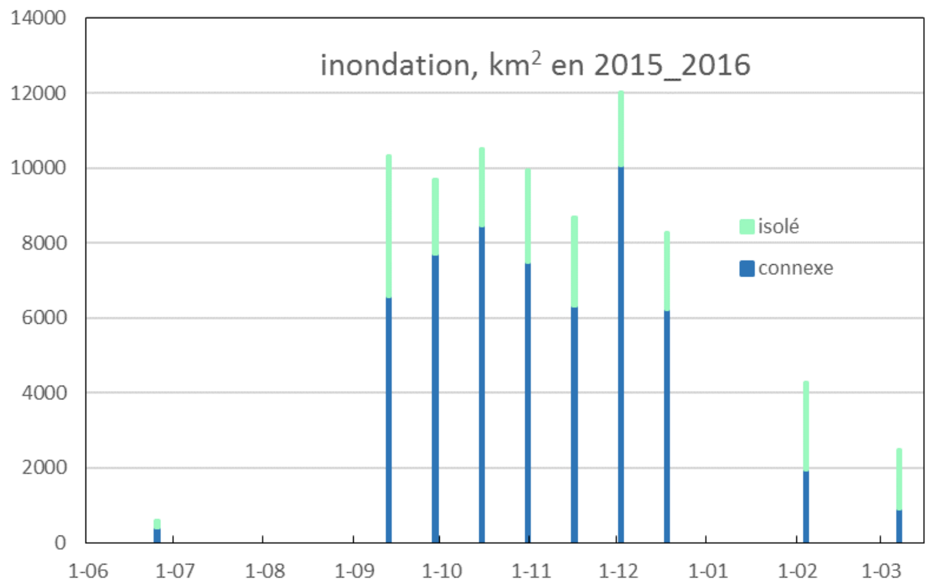


Figure 2.4. Separation of isolated (green) and connected (blue) water bodies in the Inner Niger Delta on eleven dates in the flooding season of 2015-2016, based on Landsat 8 images. Each set of Landsat 8 images (per date) was processed to calculate the connection with the river system of water bodies.

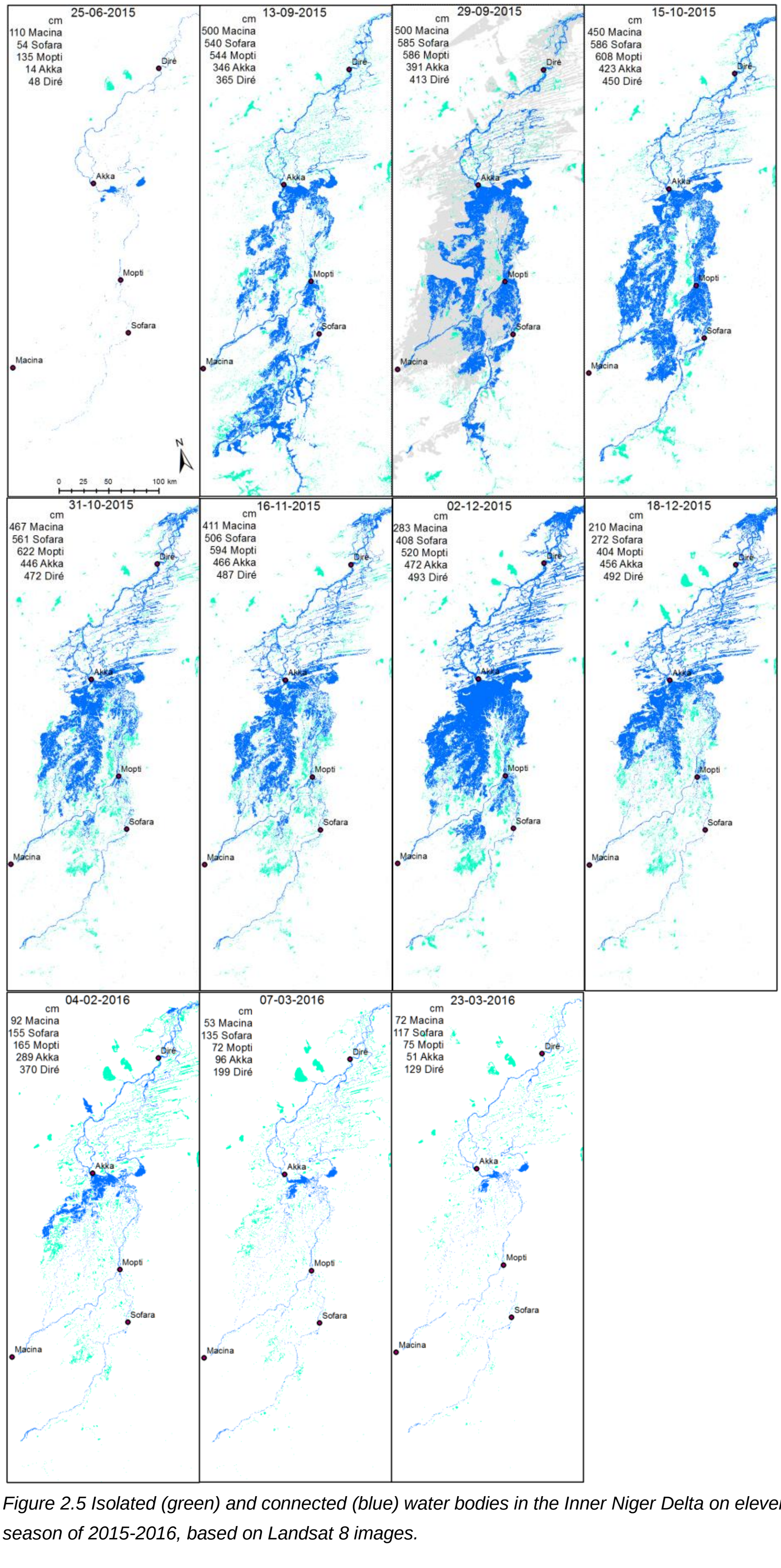


Figure 2.5 Isolated (green) and connected (blue) water bodies in the Inner Niger Delta on eleven dates in the flooding season of 2015-2016, based on Landsat 8 images.

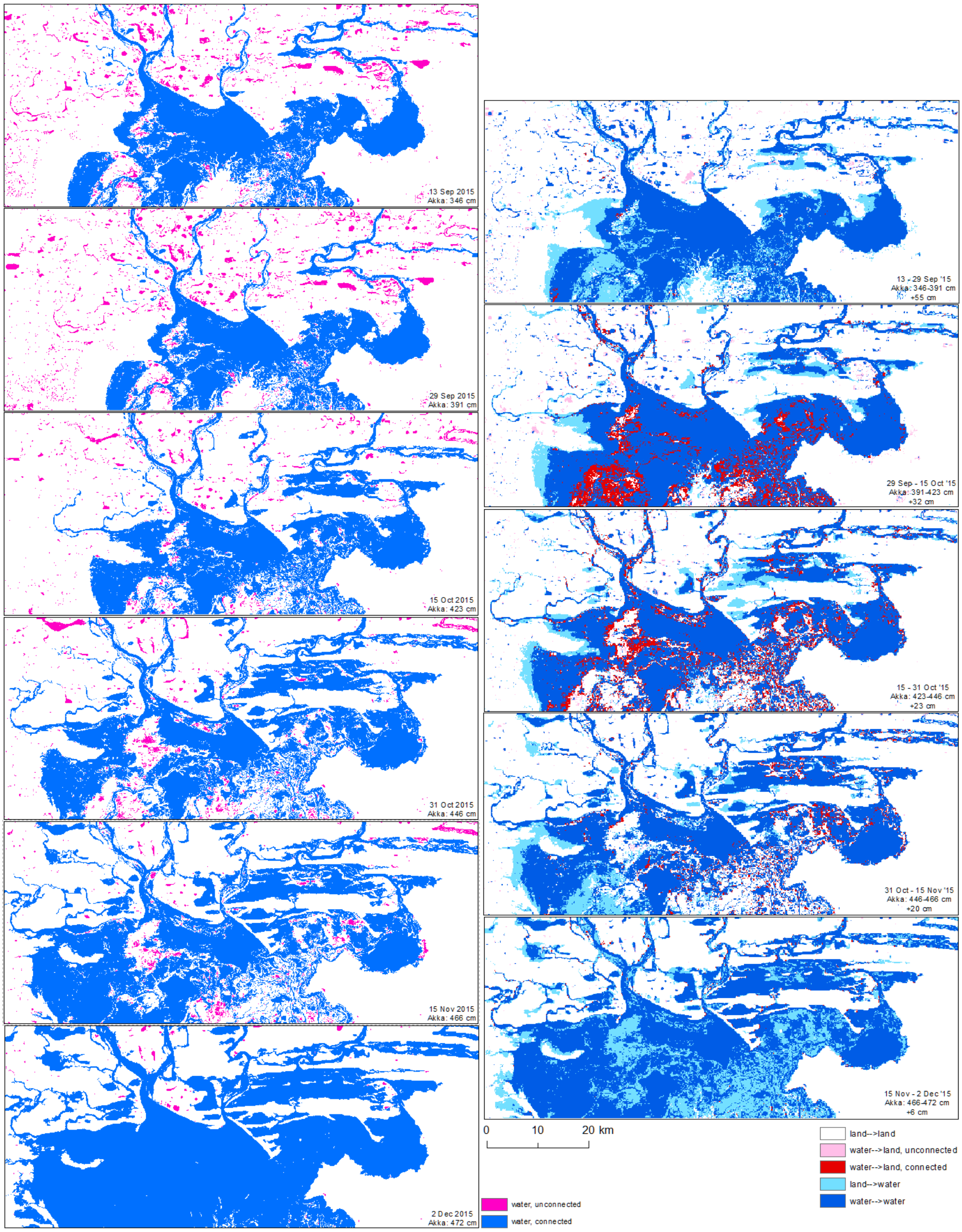


Figure 2.6 Isolated (green) and connected (blue) water bodies in the Inner Niger Delta on eleven dates in the flooding season of 2015-2016, based on Landsat 8 images.

3 Water extraction and interpolation

3.1 Extraction of water

Selection of images

The images were selected according to the process described in Sections 2.1 and 2.2. Initially, images of Landsat 4/5, 7 en 8, produced and distributed by U.S. Geological Survey (USGS) were selected. Since the amount of available Landsat 8 data products is increasing and includes nowadays additional variables as Surface Reflectance (SR), the choice was made to limit the analysis to Landsat 8 images, processed for SR. Included in the Landsat 8 Surface Reflectance product, is an additional layer describing the quality of Landsat 8 images, e.g. providing information on which pixels are affected by clouds. Using this quality information, it is possible to mask clouds, however, this will lead to parts with no-data in the processed image. Therefore it was decided to try to avoid images containing errors or clouds. As a consequence, this limited the amount of datasets representing different waterlevels that could be used to create a composite image of the entire delta.

Water extraction

The water maps were processed based on two indices. The Normalized Difference Water Index (NDWI) of McFeeters (1996) was used as first index to classify water. This index is based on the ratio between green and near- infrared wavelengths. In addition to the McFeeters NDWI, the modified water extraction method developed by Gao et al. (2016) was used, based on the ratio between near-infrared and short-wave infrared wavelengths. The McFeeters NDWI is effective in the classification of water bodies proper, while the index of Gao is effective for classification of areas with aquatic vegetation.

The water extraction of areas with much aquatic vegetation in the Inner Niger Delta needs special attention. It appeared in the initial classification that, for images taken in September and October, some water areas changed to land while the water was still rising (Fig 2.6.). This is caused by the rapid growth of Bourgou (*Echinochloa stagnina*), which is first below the water surface but, with a daily growth of 3-5 cm, rapidly rises above the water. As is shown in Fig. 2.6. this is especially the case in the central lake area south of Akka, where large Bourgou fields are present.

To fine-tune the process of water extraction for vegetated areas, threshold values (set between -1 and 1) were used to distinguish water in vegetated water bodies. The optimal threshold value differs per satellite image (depending on surface reflectance and time of year). Since a huge data set had to be processed, it was decided to use dynamic auto-thresholding based on the average pixel value of the lowest water level.

Merging to water maps

As a result of these steps composite water maps were created for 14 water levels (reference Gauge of Akka: 14, 43, 54, 140, 214, 262, 277, 346, 423, 446, 452, 466, 499, 620). Images for the same water level were merged using a unique code. For each water map a detailed check was done to avoid or repair artefacts. The combined result of these 14 water maps are shown in Fig. 3.1.

3.2 Interpolation method

The created composite water maps were used as input for the interpolation process. First, contour lines were generated that represent the outer boundary of the water extent for each water level. The outer boundaries represent local elevation of the landscape. The contour list (0, 14, 54, 140, 214, 262, 277, 346, 423, 446, 452, 466, 499 and 620 cm), is used as input for the “Topo to Raster” tool in ArcGIS Pro (http://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/how-topo-to-raster-works.htm).

By using this tool, the water contours that were derived from satellite imagery are preserved in the interpolated raster. The tool interpolates elevation values for the raster and ensures that a hydrologically correct digital elevation model (DEM) is created, with a correct representation of ridges and streams. The interpolation technique is a variant of the discretized thin plate spline technique. Input settings are: cellsize 30, 50 iterations, enforce drainage, z values between 0 and 620. Default tolerance settings were used.

Because the IND is too large to perform the interpolation in one run, the area had to be divided into six sections and the procedure was repeated for each section. The six sections have adequate overlap to avoid edge effects that are produced during interpolation. Finally, the sections were merged to a single raster product, using the “Mosaic to New Raster” tool with the “Blend” option in ArcGIS Pro. The result is shown in Fig. 3.1.

It is important to realize that when the difference in height between the input contours is large, the interpolation result will be less accurate than for closely spaced input contours. E.g. between 500 and 620 cm, there are no input contours, whilst between 400 and 500 cm, five input contours are available.

In the final DEM some artefacts occur which are only visible at a higher zoom level (Fig. 3.2). These artefacts are mainly found in steep areas where contours are very closely spaced. They are probably caused by multiple input contours crossing a single output pixel. By digitizing cliff lines and using these as additional input for the “Topo to Raster” interpolation, it may be possible to reduce these errors, since cliff lines permit a break in continuity between neighbouring cell values on each side of the cliff lines.

Figure 3.2 Example of an interpolation artefact.

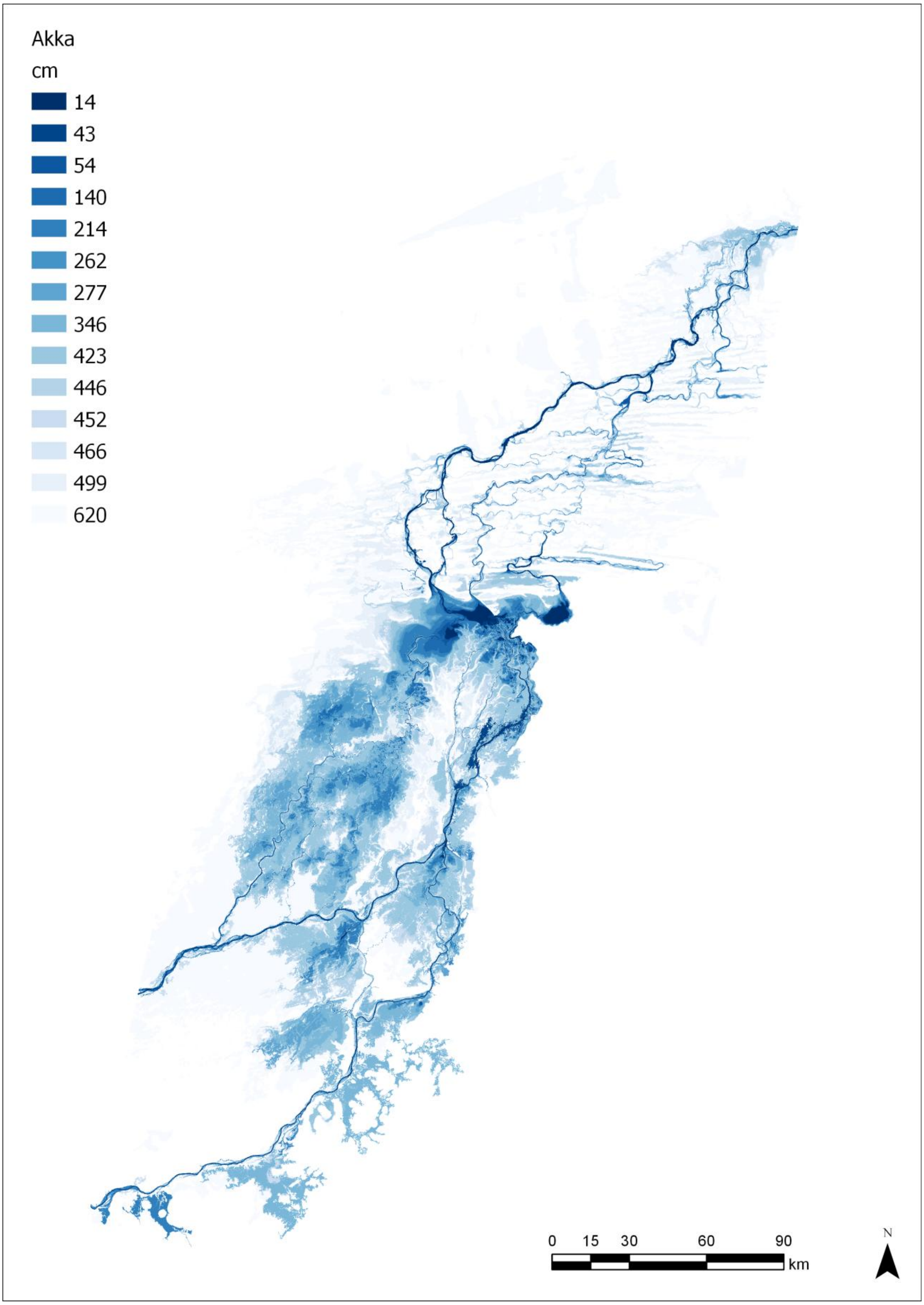


Figure 3.1. Combined water map of the Inner Niger Delta for 14 different water levels relevant to the Gauge of Akka. Explanation in the text.

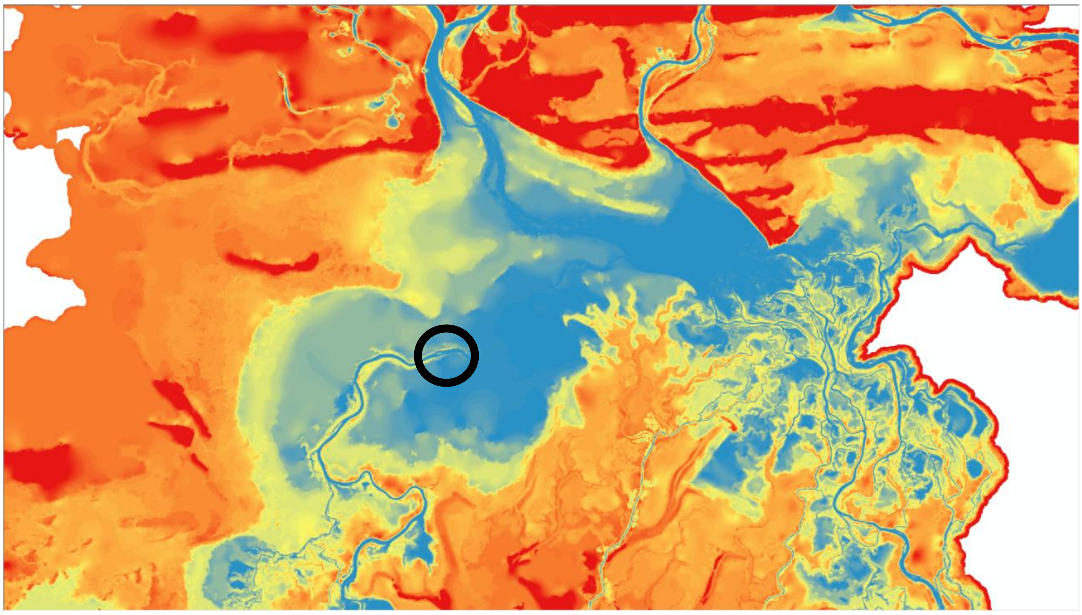
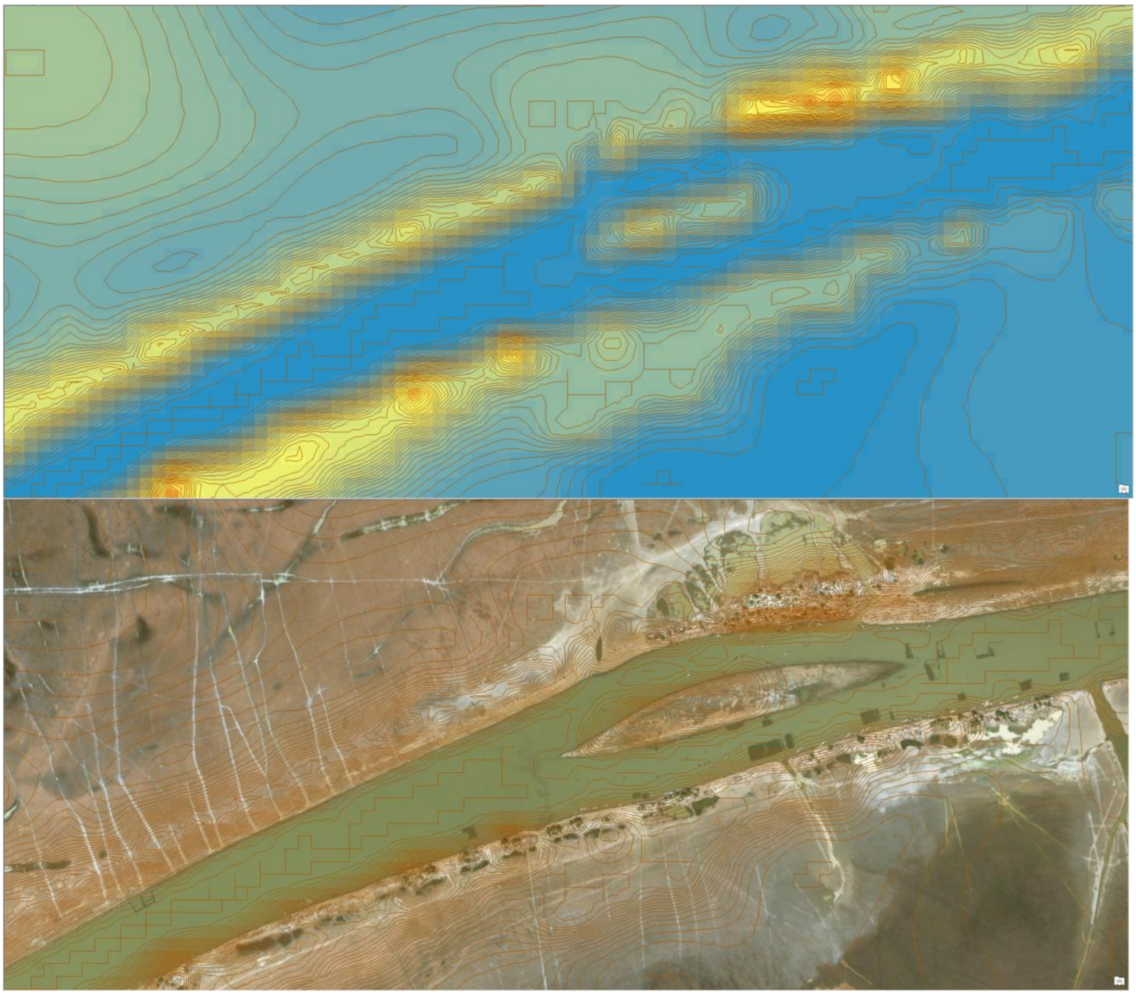


Figure 4.1. Example of the detailed flooding model in the central lake area (Lac Walado, Lac Débo). The area in the black circle is shown in detail below. In these maps the 10 cm contours are shown. The DEM is very accurate as can be seen at the village, which is situated on the higher part of the levee (blue = low area; yellow = high area).



4 Results and products

4.1 Flooding model and DEM

The ultimate result of the interpolation process is a Digital Elevation Model. Based on the elevation model, contour lines can be generated at each desired interval, using GIS software. Figure 4.1. gives an example of the central lake area (only contours). The DEM is the basis of the flooding model but it can also be used for various other calculations such as water depth as a function of peak flood level, water surface area as a function of peak flood level (Fig. 4.2), flood duration and land use. A further example is given in Fig. 4.3 in which the 10 cm contours area shown for a small area in Lac Walado.

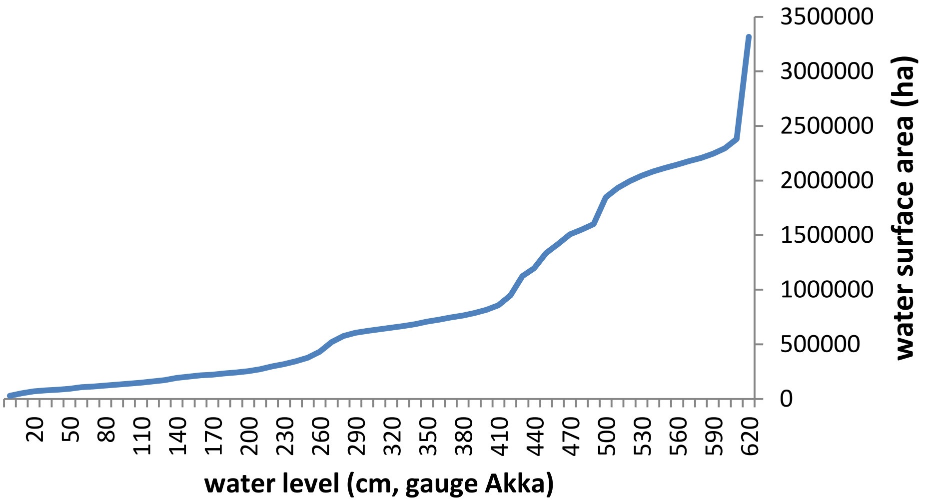


Figure 4.2. Surface area as a function of the height of the (water) level at Akka in the Inner Niger Delta.

4.2 Products

The flooding model results in several products which can be used for further purposes. These products are:

Tiff file – IND_flooding_model_v20181204_WGS84.tif
This is a raster file with a 30 x 30 meter pixel resolution. The raster represents a Digital Elevation Model (DEM) of the IND. The tiff is projected in the WGS84 Geographic coordinate system. Pixel values range from 0 to 620 and represent elevation in centimeters.

10 cm contour shapefile - IND_flooding_model_v20181204_WGS84_contours_10cm.shp
This is a vector layer with contours generated at 10 cm intervals based on the DEM.

Websites – the flooding model is used in the website of OPIDIN and ONISDIN, to ensure that these website use the most accurate flooding maps possible.

2D animation – the flooding is visualised in a 2D model for the Inner Niger Delta. This 2D animation can be found via the website ONISDIN, and is also available on YouTube (https://youtu.be/4-PDbSaocQM).

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Appendix 1. page 10-18

The days for which Landsat satellite images are available for path 196-198 and row 48-51, indicated with a x in column 2-13.
Cells marked black were used in the old model.
Cells marked yellow have been added into the new model, however, only images for path 197 were used.
Column 14-18 gives the water level in the five major hydrological stations (see Fig. 1). The last columns show whether the water was still increasing (1) or already in decline (blank) for the different days.

	196=east				197=middle				198=west				water level					1= water still incoming at this station				
date	**48**	**49**	**50**	**51**	**48**	**49**	**50**	**51**	**48**	**49**	**50**	**51**	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
9-05-84										x			70	0	71	-27	25	1	1	1	1	1
25-05-84										x			78	0	70	-46	18	1	1	1	1	1
19-06-84					x	x	x						119	89	136	23	18	1	1	1	1	1
26-06-84										x	x		120	67	151	45	67	1	1	1	1	1
28-06-84	x	x	x										120	61	152	47	77	1	1	1	1	1
5-07-84					x	x	x	x					134	50	149	52	90	1	1	1	1	1
28-07-84									x	x	x		207	44	241	99	134	1	1	1	1	1
30-07-84		x	x										214	53	243	108	142	1	1	1	1	1
6-08-84						[redacted]	[redacted]						236	76	269	140	170	1	1	1	1	1
29-08-84									x	x			355	191	385	238	266	1	1	1	1	1
7-09-84					x	x							344	234	399	267	299	1	1	1	1	1
14-09-84										x	x	x	337	223	395	282	317	1	1	1	1	1
16-09-84	x	x											336	225	391	286	320	1	1	1	1	1
16-10-84									x	x	x	x	397	304	436	317	358	1		1	1	1
18-10-84	x	x	x	x									391	302	439	319	359			1	1	1
25-10-84					x	x	[redacted]	x					322	284	435	331	367				1	1
10-11-84					x	[redacted]	[redacted]	x					199	175	326	327	375					1
8-07-85						[redacted]	[redacted]						97	0	137	-2	20	1	1	1	1	1
21-08-86	x	x	x	x									240	207	298	167	204	1	1	1	1	1
8-10-86			x	x									491	411	534	360	389			1	1	1
24-10-86	x												346	360	504	385	417				1	1
4-05-87	x	x	x	x									63	-34	74	-3	50	1	1	1	1	1
20-05-87	x												91	-49	115	1	36	1	1	1	1	1
21-06-87	x												126	0	114	13	63	1	1	1	1	1
9-09-87	x												387	259	408	264	298	1	1	1	1	1
2-10-87					x	[redacted]	[redacted]	x					401	341	444	317	357	1	1	1	1	1
3-10-87	x	x											416	342	445	318	358	1	1	1	1	1
9-10-87											x		446	351	466	328	366	1	1	1	1	1
18-10-87					x	[redacted]	[redacted]						415	349	481	343	378				1	1
10-11-87									x	x	x	x	300	247	415	358	400				1	1
5-05-88					x	x	x	x					53	-11	68	-32	24	1	1	1	1	1
14-05-88	x	x	x	x									46	-21	63	-31	21	1	1	1	1	1
30-06-88						x							115	-34	68	-46	-11	1	1	1	1	1
7-07-88									x	x	x		107	25	132	-13	-12	1	1	1	1	1
9-07-88				x									116	22	130	10	-2	1	1	1	1	1
16-07-88					x	x	x	x					151	119	176	43	57	1	1	1	1	1
25-07-88		x	x										217	202	264	92	109	1	1	1	1	1
8-08-88									x				240	314	337	186	217	1	1	1	1	1
10-08-88	x	x	x	x									267	329	354	194	227	1	1	1	1	1
24-08-88									x	x			383	349	414	264	297	1	1	1	1	1
26-08-88	x												387	387	440	271	305	1	1	1	1	1
2-09-88					x	x							441	432	490	302	328	1	1	1	1	1

date	48	49	50	51	48	49	50	51	48	49	50	51	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
9-09-88									x	x			447	477	521	335	364	1	1	1	1	1
18-09-88					x	x							502	501	548	368	393	1	1	1	1	1
25-09-88										x			504	511	563	383	408		1	1	1	1
27-09-88	x	x	x										475	513	566	388	415		1	1	1	1
11-10-88									x		x	x	401	505	570	416	443			1	1	1
13-10-88	x	x	x	x									378	502	568	419	445				1	1
20-10-88					x	x	x	x					320	477	549	426	452				1	1
27-10-88									x	x	x		268	444	513	429	456				1	1
5-11-88							x	x					226	373	445	423	459					1
29-08-89	x												331	380	398	232	259	1	1	1	1	1
21-09-89					x								397	487	506	324	346	1	1	1	1	1
30-09-89				x									383	490	516	344	376			1	1	1
14-10-89											x	x	364	457	510	370	404				1	1
23-10-89						x	x						429	414	511	380	413				1	1
16-08-90	x	x	x										281	402	408	233	258	1	1	1	1	1
23-08-90					**x**	**x**	**x**	**x**					334	426	434	262	288	1	1	1	1	1
30-08-90									x	x			367	411	454	287	315	1	1	1	1	1
1-09-90	x		x										365	405	458	292	323	1	1	1	1	1
15-09-90									x	x			399	388	478	321	358	1	1	1	1	1
17-09-90	x	x	x										403	391	478	324	362	1	1	1	1	1
24-09-90					**x**	**x**	**x**	**x**					449	401	488	334	374	1	1	1	1	1
1-10-90									x	x	x	x	445	400	504	344	385			1	1	1
3-10-90	x	x	x	x									436	402	506	348	386			1	1	1
10-10-90					**x**	**x**	**x**	**x**					432	402	510	358	396			1	1	1
17-10-90									x	x	x	x	387	380	502	367	402				1	1
26-10-90								x					335	326	468	373	409				1	1
2-11-90									x	x	x	x	293	277	428	372	410					1
4-11-90	x	x	x	x									282	262	415	370	410					1
11-09-91								x					414	472	502	313	351	1	1	1	1	1
27-09-91								x					417	476	524	353	390			1	1	1
5-05-94									x	x	**x**	**x**	72	-4	95	0	42	1	1	1	1	1
7-05-94			x	x									60	-6	99	0	43	1	1	1	1	1
14-05-94					x	x							74	-8	96	0	41	1	1	1	1	1
21-05-94										x	x		63	-12	91	0	42	1	1	1	1	1
23-05-94	x	x	x	x									61	-13	98	0	42	1	1	1	1	1
30-05-94					x	x							51	-16	99	0	39	1	1	1	1	1
6-06-94									x				74	35	82	-14	38	1	1	1	1	1
8-06-94	x	x											90	31	91	-21	37	1	1	1	1	1
15-06-94					**x**	**x**	**x**	**x**					108	23	126	-3	30	1	1	1	1	1
10-07-94	x		x										261	100	246	93	124	1	1	1	1	1
17-07-94					x	x	x						257	123	291	131	151	1	1	1	1	1
8-05-95									x	x	**x**	**x**	88	19	144	46	98	1	1	1	1	1
17-05-95					x	x							71	10	112	40	98	1	1	1	1	1
24-05-95									x	x	x		83	3	117	23	96	1	1	1	1	1
26-05-95	x	x	x	x									76	0	117	20	92	1	1	1	1	1

date	48	49	50	51	48	49	50	51	48	49	50	51	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
9-06-95									x	x	x	x	94	20	144	41	83	1	1	1	1	1
11-06-95	x	x	x										130	32	139	46	84	1	1	1	1	1
18-06-95					x	x	x	x					126	29	171	54	95	1	1	1	1	1
25-06-95									x	x	x	x	140	26	184	66	105	1	1	1	1	1
27-06-95		x	x										123	25	190	67	109	1	1	1	1	1
20-07-95						x	x						170	71	198	76	120	1	1	1	1	1
29-07-95			x										166	111	216	108	146	1	1	1	1	1
5-08-95					x								252	141	262	125	162	1	1	1	1	1
14-08-95	x												343	256	338	175	198	1	1	1	1	1
24-11-98										x	x	x	274	431	544	486	496					1
30-06-99	x												35	29	47	- 34.018	19	1	1	1	1	1
2-10-99									x				618	607	643	438	341			1	1	1
18-10-99											x	x	544	596	660	463	419			1	1	1
20-10-99	x	x	x	x									548	594	660	467	423			1	1	1
28-11-99						[redacted]		x					296	477	589	511	497				1	1
5-12-99									x	x	x	x	315	418	547	508	504					1
7-12-99	x	x											289	399	535	508	505					1
14-12-99					x								236	339	485	497	510					1
30-12-99							x	x					173	223	345	461	515					1
15-05-00	x	x	x	x									61	22	103	3	74	1	1	1	1	1
7-06-00								x					107	-3	134	42	74	1	1	1	1	1
30-06-00									x			x	185	88	170	65	99	1	1	1	1	1
2-07-00	x	x	x	x									176	109	190	74	103	1	1	1	1	1
17-08-00									x				364	407	440	253	286	1	1	1	1	1
26-08-00						[redacted]							374	461	478	294	322	1	1	1	1	1
4-09-00	x	x	x										418	496	511	320	352	1		1	1	1
11-09-00								x					450	514	534	340	372	1		1	1	1
18-09-00										x	x		511	526	557	358	392	1		1	1	1
27-09-00					x	[redacted]							549	528	578	381	413	1		1	1	1
4-10-00									x	x	x	x	556	0	586	395	428	1		1	1	1
6-10-00		x											563	0	588	400	432	1		1	1	1
13-10-00							x	x					582	0	595	410	445	1		1	1	1
20-10-00									x	x	x		562	0	605	424	451			1	1	1
22-10-00	x	x											554	0	607	427	455			1	1	1
29-10-00					x	[redacted]		x					520	0	607	437	465			1	1	1
5-11-00									x	x	x	x	487	0	602	448	473				1	1
7-11-00	x	x	x										465	0	600	450	475				1	1
25-05-01						x							122	-2	127	26	65	1	1	1	1	1
3-06-01	x	x	x	x									84	-13	143	39	74	1	1	1	1	1
10-06-01					x	[redacted]							104	-3	132	50	86	1	1	1	1	1
17-06-01									x				127	-2	152	60		1	1	1	1	1
3-07-01									x				150	-1	178	95		1	1	1	1	1
5-07-01	x	x											149	2	178	98	106	1	1	1	1	1

date	48	49	50	51	48	49	50	51	48	49	50	51	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
12-07-01					x								178	164	196	105	117	1	1	1	1	1
28-07-01						[redacted]							258	275	339	166	191	1	1	1	1	1
6-08-01	x	x	x	x									315	303	370	224	258	1	1	1	1	1
5-09-01									x	x			514	484	542	338	369	1	1	1	1	1
21-09-01												x	661	527	583	383	414	1	1	1	1	1
30-09-01								x					662	533	601	403	433	1	1	1	1	1
7-10-01											x		631	532	609	416	444			1	1	1
9-10-01	x	x	x	x									618	530	612	418	448			1	1	1
16-10-01					x	[redacted]							575	524	620	432	458			1	1	1
23-10-01									x	x		x	459	511	620	444	469			1	1	1
8-11-01									x				344	417	562	467	488				1	1
10-11-01	x	x	x	x									337	400	552	469	489				1	1
17-11-01							x	x					277	341	503	470	490				1	1
3-05-02										x	x	x	55	-32	113	25	79	1	1	1	1	1
6-06-02			x										95	-39	118	16	63	1	1	1	1	1
13-06-02					x	x	x	x					74	-33	120	24		1	1	1	1	1
20-06-02											x		94	-33	118	20	63	1	1	1	1	1
22-06-02	x	x	x	x									94	-35	122	11		1	1	1	1	1
6-07-02												x	152	19	166	30	65	1	1	1	1	1
15-07-02						x	x						139	72	198	64	88	1	1	1	1	1
22-07-02									x	x	x		177	114	250	89	118	1	1	1	1	1
31-07-02						x	x						190	168	254	130	163	1	1	1	1	1
7-08-02										x	x		308	217	305	158	190	1	1	1	1	1
9-08-02		x											312	244	331	167	202	1	1	1	1	1
16-08-02					x		x						364	298	391	208	236	1	1	1	1	1
23-08-02											x		391	317	433	248	274	1	1	1	1	1
1-09-02						x	x	x					387	327	448	293	317	1	1	1	1	1
8-09-02									x	x			430	345	463	308	339	1	1	1	1	1
10-09-02			x										435	351	469	316	344	1	1	1	1	1
17-09-02						x	x						466	395	495	333	361	1	1	1	1	1
26-09-02	x	x											504	416	518	352	384	1	1	1	1	1
3-10-02							x	x					514	422	533	368	396	1	1	1	1	1
12-10-02		x											442	419	536	387	418			1	1	1
19-10-02					x	x	x	x					407	421	534	395	429			1	1	1
26-10-02									x	x	x	x	422	411	537	404	436				1	1
28-10-02			x	x									421	407	526	407	439				1	1
4-11-02					x	x	x	x					348	382	510	411					1	1
11-11-02									x	x	x	x	308	341	474	411	441					1
13-11-02	x												303	327	461	411	442					1
20-11-02					x	x	x	x					256	273	404	406	443					1
6-05-03										x	x	x	70	-74	56	-38	3	1	1	1	1	1
8-05-03				x									68	-75	54	-37	2	1	1	1	1	1
15-05-03						x	x						49	-72	71	-35	2	1	1	1	1	1
22-05-03											x	x	70	-65	76	-25	4	1	1	1	1	1

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31-05-03						x	x	x					49	-53	107	-11	21	1	1	1	1	1
22-10-06					x	x							516	517	592	432	465			1	1	1
29-10-06									x	x	x	x	500	518	596	440	474			1	1	1
31-10-06	x	x	x	x									467	517	597	442	475			1	1	1
7-11-06					x	x	x	x						509	589	450	480				1	1
14-11-06									x	x	x	x		486	571	453	484				1	1
16-11-06	x	x	x	x										476	563	454	485				1	1
23-11-06					x	x	x	x						423	526	454	489					1
30-11-06											x	x		313	459	448	488					1
9-05-07									x	x	x		45	62	96	6	52	1	1	1	1	1
11-05-07	x	x	x	x									37	61	112	8	49	1	1	1	1	1
18-05-07					x	x	x	x					47	60	101	-6	42	1	1	1	1	1
25-05-07									x	x	x		72	58	105	-13	34	1	1	1	1	1
3-06-07					x								64	55	119	-6	27	1	1	1	1	1
10-06-07									x	x	x	x	66	51	111	7	22	1	1	1	1	1
12-06-07	x	x	x	x									44	50	110	7	22	1	1	1	1	1
26-06-07									x		x	x	66	54	116	3	45	1	1	1	1	1
28-06-07	x	x	x	x									66	55	112	7	45	1	1	1	1	1
12-07-07											x		40	147	110	34	67	1	1	1	1	1
30-07-07	x	x	x										178	232	179	37	67	1	1	1	1	1
13-08-07									x	x	x		375	253	416	177	173	1	1	1	1	1
15-08-07	x	x											392	252	448	195	194	1	1	1	1	1
22-08-07					x								402	249	481	256	261	1	1	1	1	1
7-09-07					x								576	242	570	339	358	1	1	1	1	1
14-09-07									x	x	x	x	603	240	595	367	389	1	1	1	1	1
16-09-07	x	x											609	239	604	374	395	1	1	1	1	1
23-09-07					x			x						236	620	394	416	1	1	1	1	1
30-09-07									x		x	x		233	630	410	434			1	1	1
2-10-07	x	x	x	x									537	232	632	414	436			1	1	1
15-06-09									x	x		x	75	78	111	2	38	1	1	1	1	1
17-06-09	x	x	x	x									70	77	112	2	43	1	1	1	1	1
24-06-09						x	x	x					63	76	113	3	53	1	1	1	1	1
10-07-09					x	x							143	75	169	5	45	1	1	1	1	1
17-07-09									x	x			162	79	180	32	63	1	1	1	1	1
2-08-09											x		214	112	244	82	122	1	1	1	1	1
11-08-09					x								244	107	261	127	163	1	1	1	1	1
18-08-09											x		362	206	338	165	194	1	1	1	1	1
27-08-09						x							439	354	448	213	248	1	1	1	1	1
3-09-09									x	x			508	425	497	283	292	1	1	1	1	1
5-09-09	x	x	x										522	444	513	294	308	1	1	1	1	1
12-09-09					x								587	499	551	325	342	1	1	1	1	1
19-09-09									x	x	x	x	636	538	582	349	375	1	1	1	1	1
21-09-09	x												634	548	586	359	382		1	1	1	1
28-09-09					x			x					625	568	605	385	405		1	1	1	1
5-10-09									x	x	x	x	617	579	619	403	426		1	1	1	1

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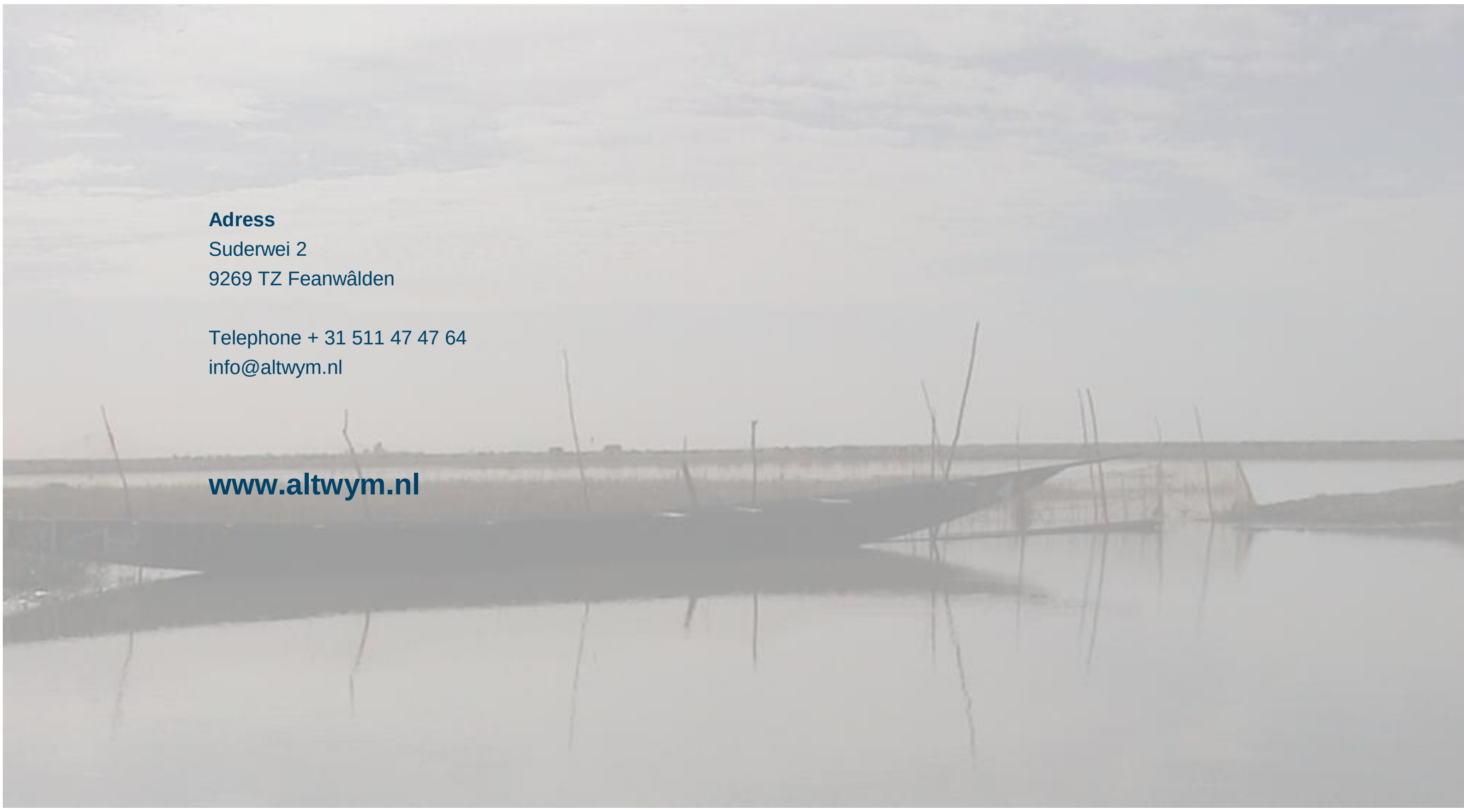
7-10-09	x	x	x	x									595	580	621	408	434			1	1	1
14-10-09					x	x	x	x					536	577	628	424	448			1	1	1
21-10-09									x	x	x	x	450	565	629	439	461				1	1
30-10-09					x								449	542	616	459	476				1	1
6-11-09									x	x	x	x	435	529	617	488	488				1	1
8-11-09	x	x	x	x									435	521	613	490	490				1	1
15-11-09					x	x	x	x					412	487	596	495	495				1	1
22-11-09									x			x	334	452	566	497	500				1	1
24-11-09	x	x	x	x									315	442	557	497	501				1	1
10-05-10					x	x	x	x					55	73	86	18	42	1	1	1	1	1
19-05-10		x	x	x									111	83	120	14	24	1	1	1	1	1
26-05-10					x	x	x	x					97	70	139	9	36	1	1	1	1	1
2-06-10									x		x		78	69	119	8	58	1	1	1	1	1
11-06-10							x						111	80	127	14	68	1	1	1	1	1
18-06-10									x	x	x	x	170	81	169	38	66	1	1	1	1	1
20-06-10	x	x											162	87	191	43	68	1	1	1	1	1
4-07-10									x	x	x	x	190	115	230	90	112	1	1	1	1	1
6-07-10	x	x	x										185	114	232	94	117	1	1	1	1	1
13-07-10					x	x							191	123	233	111	143	1	1	1	1	1
5-08-10									x	x	x		291	313	384	207	235	1	1	1	1	1
24-10-10									x	x	x		498	618	638	474	491			1	1	1
26-10-10	x												517	615	641	475	494			1	1	1
18-11-10					x	x	x	x					423	568	638	499	512				1	1
25-11-10									x	x	x	x	346	548	618	504	517					1
27-11-10	x	x	x	x									327	541	610	504	518					1
4-12-10					x	x	x	x					301	509	582	501	520					1
11-12-10										x	x	x	261	460	543	494	522					1
13-12-10		x	x	x									253	441	531	492	523					1
6-05-11	x	x	x	x									27	95	126	39	86	1	1	1	1	1
13-05-11					x								83	73	130	28	84	1	1	1	1	1
7-06-11	x												106	80	148	44	86	1	1	1	1	1
14-06-11					x		x	x					109	72	137	39	89	1	1	1	1	1
23-06-11	x	x											43	79	119	35	85	1	1	1	1	1
9-07-11	x												208	79	219	56	86	1	1	1	1	1
23-07-11									x	x	x		220	89	263	109	141	1	1	1	1	1
1-08-11							x						256	112	282	143	181	1	1	1	1	1
10-08-11	x	x	x	x									261	122	299	179	217	1	1	1	1	1
24-08-11									x	x	x		415	306	411	236	267	1	1	1	1	1
2-09-11					x	x	x	x					440	400	483	277	309	1	1	1	1	1
11-09-11	x	x	x										374	419	503	313	348	1	1	1	1	1
18-09-11					x								355	413	494	332	369	1	1	1	1	1
25-09-11									x	x	x	x	399	440	488	347	384	1	1	1	1	1
27-09-11	x	x	x										406	453	493	349	388	1	1	1	1	1
29-10-11	x	x	x	x									359	447	519	398	434				1	1
12-11-11									x	x	x	x	319	383	475	404	444				1	1

date	48	49	50	51	48	49	50	51	48	49	50	51	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
11-05-13	x	x	x	x									40	70	90	9	71	1	1	1	1	1
25-05-13									x	x	x	x	80	80	120	7	53	1	1	1	1	1
27-05-13	x	x											84	79	125	4	52	1	1	1	1	1
3-06-13					x	x	x	x					91	76	134	8	50	1	1	1	1	1
10-06-13									x	x	x	x	33	75	111	16	58	1	1	1	1	1
12-06-13	x	x	x	x									32	75	90	15	61	1	1	1	1	1
19-06-13					x	x	x	x					64	79	99	8	63	1	1	1	1	1
28-06-13	x												62	78	101	3	46	1	1	1	1	1
12-07-13									x	x	x		125	87	148	15	50	1	1	1	1	1
14-07-13	x	x	x	x									149	87	156	20	52	1	1	1	1	1
21-07-13					x	x	x						146	100	188	43	67	1	1	1	1	1
28-07-13									x	x	x		253	108	223	71	93	1	1	1	1	1
22-08-13					x	x	x	x						336	409	214	241	1	1	1	1	1
29-08-13									x	x				442	507	0	277	1	1	1	1	1
31-08-13	x		x										576	459	525	0	272	1	1	1	1	1
7-09-13					x	x	x						592	496	565	315	338	1	1	1	1	1
14-09-13									x	x	x		615	512	583	352	371	1	1	1	1	1
16-09-13	x	x	x	x									619	517	587	356	379	1	1	1	1	1
23-09-13					x	x	x	x					616	533	602	377	405		1	1	1	1
30-09-13											x	x	584	547	609	398	426		1	1	1	1
2-10-13		x	x	x									572	548	610	404	432		1	1	1	1
9-10-13					x			x					543	552	617	420	449		1	1	1	1
16-10-13											x	x	474	552	621	434	461			1	1	1
18-10-13	x			x									457	549	621	439	464				1	1
25-10-13					x	x		x					447	534	612	451	475				1	1
3-11-13	x	x	x	x									386	503	596	467	486				1	1
10-11-13					x	x	x	x					338	464	566	475	492				1	1
17-11-13									x	x	x	x	298	406	527	477	497				1	1
26-11-13					x	x	x	x					249	326	452	473	501					1
5-05-14					x								61	0	118	0	39	1	1	1	1	1
12-05-14									x	x	x	x	40		84	2	34	1	1	1	1	1
14-05-14	x		x										40	0	79	2	36	1	1	1	1	1
21-05-14					x	x	x	x					80	0	117	-10	45	1	1	1	1	1
28-05-14									x				78	0	136	3	31	1	1	1	1	1
30-05-14	x		x										70	0	144	7	35	1	1	1	1	1
6-06-14					x	x	x						84	0	128	16	57	1	1	1	1	1
13-06-14									x				121	0	147	23	68	1	1	1	1	1
15-06-14	x	x	x	x									120	0	151	25	70	1	1	1	1	1
29-06-14									x	x	x	x	168		173	39	84	1	1	1	1	1
1-07-14	x	x	x	x									182	0	183	42	86	1	1	1	1	1
8-07-14						x	x	x					159	162	204	61	98	1	1	1	1	1
15-07-14									x	x	x		144	133	169	76	115	1	1	1	1	1
17-07-14	x	x											183	136	171	74	119	1	1	1	1	1
24-07-14					x								197	154	233	82	131	1	1	1	1	1

date	48	49	50	51	48	49	50	51	48	49	50	51	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
31-07-14									x	x			250	202	281	116	147	1	1	1	1	1
18-08-14	x												293	364	383	210	241	1	1	1	1	1
25-08-14					x	x	x	x					312	443	436	249	274	1	1	1	1	1
1-09-14									x	x	x	x	356	480	457	278	308	1	1	1	1	1
3-09-14	x	x											394	486	470	284	316	1	1	1	1	1
10-09-14					x								434	511	506	309	344	1	1	1	1	1
19-09-14	x	x											506	530	547	333	375	1	1	1	1	1
26-09-14					x	x	x	x					507	529	563	366	395	1	1	1	1	1
3-10-14									x				537	523	575	383.92	414			1	1	1
5-10-14	x	x		x									532	523	578	387.2	418			1	1	1
12-10-14					x	x	x	x					528	530	581	399	432			1	1	1
19-10-14									x	x	x	x	525	535	593	410.16	444			1	1	1
21-10-14	x	x	x	x									507	533	595	413.44	448			1	1	1
28-10-14					x	x	x	x					343	518	590	425	459				1	1
4-11-14									x	x	x	x	306	485	558	433	463				1	1
6-11-14	x	x	x	x									301	468	548	435	466				1	1
13-11-14					x								288	409	503	438	471				1	1
22-11-14		x	x	x									260	324	438	435	475					1
8-05-15					x	x	x	x					44	82	97	-5	50	1	1	1	1	1
15-05-15									x	x	x	x	59	82	99	-12	46	1	1	1	1	1
17-05-15	x	x	x										56	82	96	-14	46	1	1	1	1	1
24-05-15					x								49	83	89	-21	39	1	1	1	1	1
31-05-15									x	x	x		68	83	80	-28	29	1	1	1	1	1
2-06-15	x	x	x	x									70	83	83	-28	30	1	1	1	1	1
9-06-15					x								85	65	103	-21	30	1	1	1	1	1
16-06-15									x	x			97	59	123	1	32	1	1	1	1	1
18-06-15	x	x	x	x									97	54	128	5	35	1	1	1	1	1
25-06-15					x	x	x	x					110	54	135	14	48	1	1	1	1	1
2-07-15									x	x			98	128	143	24	59	1	1	1	1	1
4-07-15			x	x									109	122	135	23	62	1	1	1	1	1
11-07-15					x	x	x						121	120	147	48	75	1	1	1	1	1
18-07-15									x	x			137	125	189	41	84	1	1	1	1	1
20-07-15	x												145	120	184	43	88	1	1	1	1	1
27-07-15						x							235	132	259	72	101	1	1	1	1	1
3-08-15									x				268	180	294	122	138	1	1	1	1	1
12-08-15					x	x							300	306	371	196	212	1	1	1	1	1
19-08-15									x	x			335	340	399	240	262	1	1	1	1	1
21-08-15	x	x	x										338	340	408	251	273	1	1	1	1	1
28-08-15					x	x							376	418	445	276	305	1	1	1	1	1
6-09-15	x	x	x										441	489	510	318	341	1	1	1	1	1
13-09-15					x	x	x	x					500	540	544	346	365	1	1	1	1	1
22-09-15			x	x									503	582	582	379	391		1	1	1	1
29-09-15					x	x	x	x					454	585	586	391	413		1	1	1	1
8-10-15	x	x	x	x									501	586	597	410	436			1	1	1

1-05-16									x	x		x	86	14	118	8		1	1	1	1	1
3-05-16	x	x	x	x									67	95	125	11		1	1	1	1	1
10-05-16					x	x		x					83	93	95	15		1	1	1	1	1
17-05-16									x	x	x	x			122			1	1	1	1	1
19-05-16	x		x	x											117			1	1	1	1	1
26-05-16							x	x							128			1	1	1	1	1
2-06-16									x	x	x	x			110			1	1	1	1	1

date	48	49	50	51	48	49	50	51	48	49	50	51	macina	sofara	mopti	akka	dire	i_mac	i_sof	i_mop	i_akk	i_dir
4-06-16	x	x	x												100			1	1	1	1	1
11-06-16					x										105			1	1	1	1	1
18-06-16									x	x	x	x			113			1	1	1	1	1
20-06-16	x	x	x												100			1	1	1	1	1
27-06-16					x	x									82			1	1	1	1	1
4-07-16									x						87			1	1	1	1	1
6-07-16	x	x													95			1	1	1	1	1
13-07-16							x	x							148			1	1	1	1	1
29-07-16					x	x												1	1	1	1	1
5-08-16									x	x	x				425			1	1	1	1	1
7-08-16	x	x													438			1	1	1	1	1
14-08-16					x	x									500			1	1	1	1	1
30-08-16						x	x	x							587			1	1	1	1	1
6-09-16									x	x	x				607			1	1	1	1	1
8-09-16	x														614			1	1	1	1	1
22-09-16									x	x	x	x			642			1	1	1	1	1
24-09-16	x	x	x	x											644					1	1	1
1-10-16					x	x	x	x							647					1	1	1
8-10-16									x	x	x	x			650					1	1	1
10-10-16	x	x	x	x											652					1	1	1
15-10-15					x	x	x	x					450	586	608	423	450			1	1	1
17-10-16					x	x	x	x							657					1	1	1
22-10-15									x					579	615	434	462			1	1	1
24-10-15	x	x	x	x										575	618	437	464			1	1	1
31-10-15					x	x	x	x					467	561	622	446	472			1	1	1
7-11-15									x	x	x	x	435	542	610	455	479				1	1
9-11-15	x	x	x	x									436	535	606	457	479				1	1
16-11-15					x	x	x	x					411	506	594	466	487				1	1
25-11-15	x	x	x	x									330	456	559	472	491				1	1
2-12-15					x	x	x	x					283	408	520	472	493				1	1



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