Final Report – Mapping and analysis of wetlands and rivers at Kafa Biosphere Reserve

Nansenstr. 17
12047 Berlin, Germany
www.geosysnet.de

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Biodiversity under Climate Change: Community Based Conservation, Management and Development Concepts for the Wild Coffee Forests

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Report prepared by: Elisabeth Dresen

Co-authors: Dr. Cosima Tegetmeyer, Fanny Mundt, Martin Dresen

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1. Introduction

The contract 'Mapping and analysis of wetlands and rivers at Kafa Biosphere Reserve' is part of the project 'Biodiversity under Climate Change: Community Based Conservation, Management and Development Concepts for the Wild Coffee Forests'. It is the initial inventur of all rivers and wetlands within the Kafa Biosphere Reserve, thus the baseline for following tasks and management decisions. The main tasks of the assignment are mapping of all rivers and wetlands and an in-depth analysis of three pilot sites (one river, two wetlands) in the Kafa Biosphere Reserve for the purpose of preservation of wetlands, flood plains and watersheds as hotspots of biodiversity and carbon sinks.

Specific objectives according to the Terms of Reference are to:

- Give a full picture of the existent types of aquatic ecosystems (e.g. rivers, wetlands and other aquatic habitats) inside Kafa Biosphere Reserve/ Kafa Zone,
- Determine underlying threats to aquatic habitats inside Kafa Biosphere Reserve/ Kafa Zone (e.g. smallholders use, investment projects, road construction),
- Categorize the mapped aquatic habitats according to their current natural state and need of action for preservation as follows:
  - Area to be strictly protected as core zone due to outstanding natural value or as unspoilt pristine reference area,
  - Area to be restored and renaturated in order to regain a most natural state,
  - Area to be transferred to sustainable community management and accounted for buffer zone,
  - Area of least concern,
- Identify three pilot sites for in-depth analysis in close consultation with NABU,
- Gather and compile all relevant data (habitat type, ecology, water supply, water flow, soil types, hemeroby index, use, fauna, flora, threats etc.) of the pilot sites,
- Develop management and monitoring recommendations for selected sites of interest including the pilot sites.

2. List of abbreviations

BMC	Billion Metric Cube
BR	Biosphere Reserve
CC	Carrying Capacity
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EMA	Ethiopian Mapping Authority
GD	Group discussion
GDEM	ASTER Global Digital Elevation Map – free of charge
GIS	Geographic Information System
HGM	Hydrogeomorphic classification system

HM	Hydrologic modelling
IDI	In depth interview
LULC	Land Use Land Cover
MoARD	Ministry of Agriculture and Rural Development
MoWR	Ministry of Water and Energy
PNV	Potential Natural Vegetation
PRA	Participatory Rural Appraisal
RivEX	GIS tool designed to process vector river networks
RS	Remote Sensing
TWI	Topographic Wetness Index
W/D ratio	Width/ depth ratio

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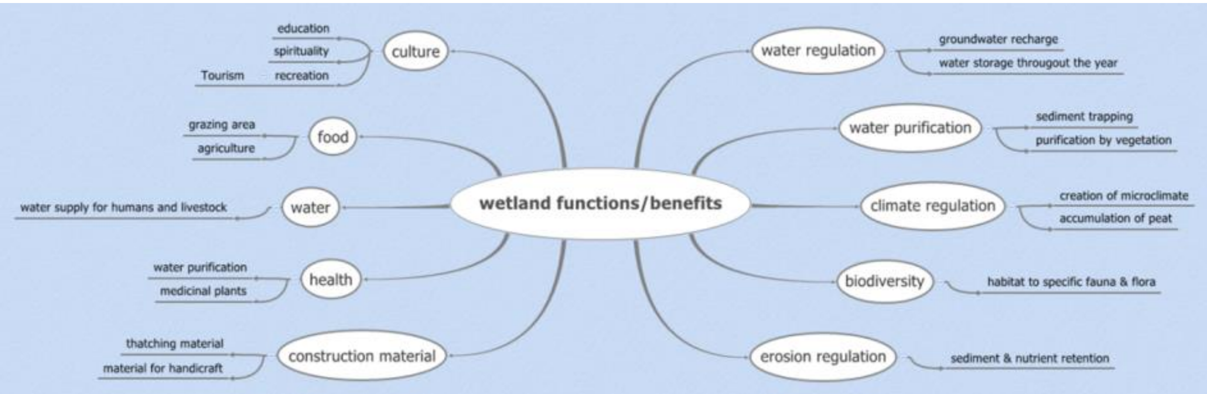
PART 1 – Framework & Study Area

1. Conservation of Wetlands – Conceptual framework

No doubt, the role and importance of wetlands in Ethiopia is often underestimated, which leads to conversion by draining to allow grazing and agriculture. This development might increase the food production and spatial area for grazing but a lot of benefits for the whole community and important wetlands functions get lost. In the figure below (Figure 1), the wetland ecosystem functions and benefits are shown.

Figure 1: Wetland functions and benefits (by F. Mundt)



In the context of conservation, development and the management of Ethiopian wetlands, A. Wood formulated three catchy slogans(Wood 2000):

- ‘Recognise the true value of wetlands to the nation and its people. It is costly to replace their functions and products from other sources.’
- ‘Use wetlands wisely to maintain their benefits for people and the environment.’
- ‘If you have to convert wetlands, do it carefully & leave some unchanged.’

The trade-off between nature conservation and development is especially delicate in complex ecosystems like wetlands. To create a baseline for further activities and to be able to give management recommendations, we worked out a classification scheme for rivers and wetlands within the Kafa Biosphere Reserve. The conceptual framework for classifying the rivers and wetlands in the different protection zones consists of the evaluation of the following criteria:

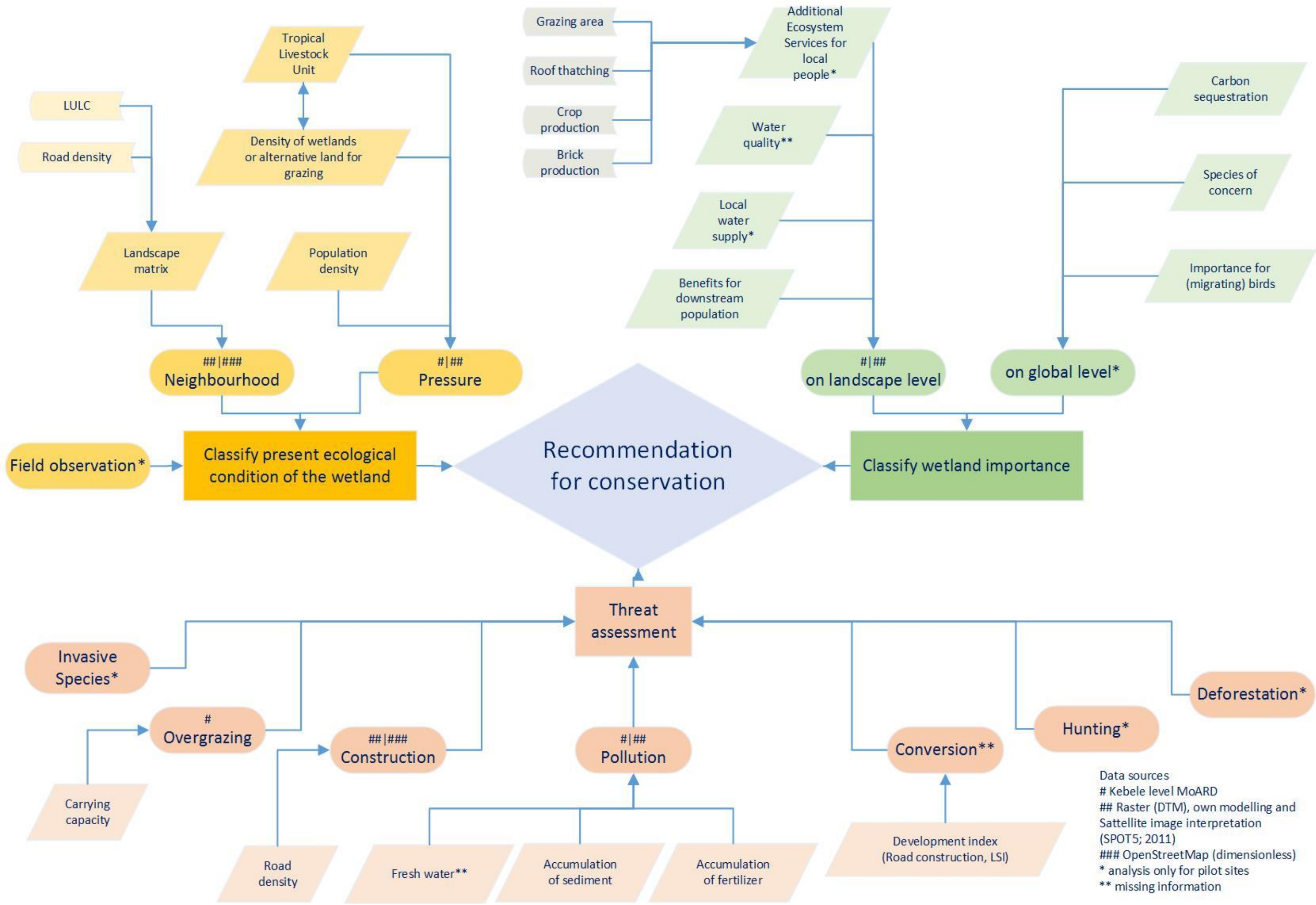
a) biophysical[1]
b) socio-economical[2]
c) ecological condition

A semi-quantitative multi-criteria analysis is conducted to classify wetlands and river systems according to the present ecological condition, their importance on landscape and global level, and

[1] a) for whole Kafa BR
[2] b-c) for pilot sites

existing and potential threats of wetlands. Combined with the information from expert interviews, online questionnaire and a literature review (Hillman & Abebe 1993; EWNRA 2008; EWNRA 2013; Dixon 2002; Haslam 2003; Survey n.d.; Hailu 2009; Gebresllassie et al. 2014; Desta 2003; Abbot & Hailu n.d.; Wood 2000), influencing criteria are weighted and consequently lead to recommendations for conservation and management. The full approach is applied on local level (pilot sites), where socioeconomic data is collected through questionnaires and field visits enhance the data base. The method is based on the concept of a land suitability classification (Fao 1991; Ritung et al. 2007; Ramachandra et al. 2005). At regional level, wetlands are classified according to biophysical, demographic and vegetation information. The full models can be found in the Appendix (Figure 52; Figure 53).

Figure 2: Conceptual model for the conservation recommendation in Kafa BR

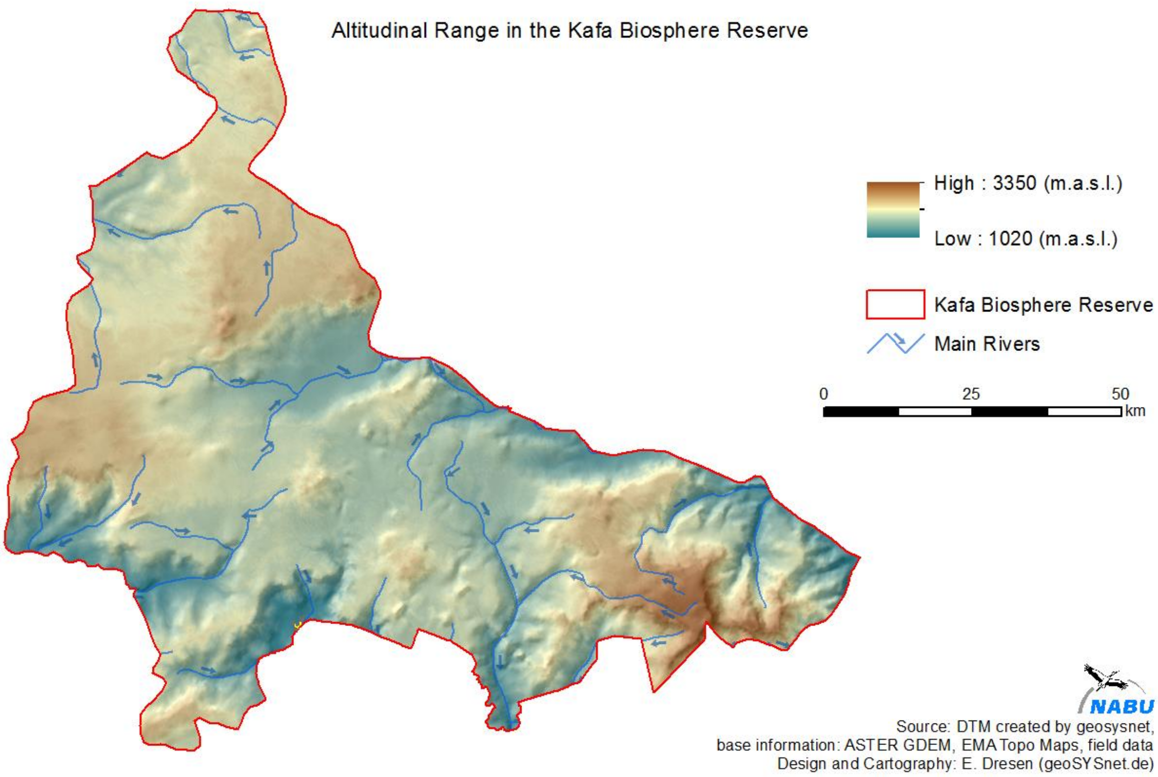


2. Biophysical characteristics of Kafa Biosphere Reserve

a. Topography

All information concerning the topography of the Kafa BR are derived from the baseline data (Digital Terrain Model(Dresen 2014)), interpolated for this contract.

The Kafa Zone has an extremely diverse topography. Ranging from 1,020 m.a.s.l. to 3,350 m.a.s.l. with its lowest point eastwards of Wacha in the Sherma plain and its highest mountain range south of Kaka (Angiyo Kolla mountain range). The map shows the altitudinal range within the Kafa BR (Map 1).



Map 1: Altitudinal Rage in the Kafa Biosphere Reserve

The altitudinal variation results in extreme slope gradients, ranging from flat lowlands (e.g. south of Konda in the Gojeb wetland) to extremely steep (>60°) areas (e.g. Machachi forest, 35°59'9.152"E 7°11'26.108"N). Of the total Biosphere spatial extent, around 1.2 percent (8,360 ha) is very steep terrain (>35°). Most of the steep terrain is covered by tropical mountain cloud forest (Whitmore 1993) and plantations (80%), but also agriculture can be found (12%). All other steep areas are Savannah or covered by bushland.

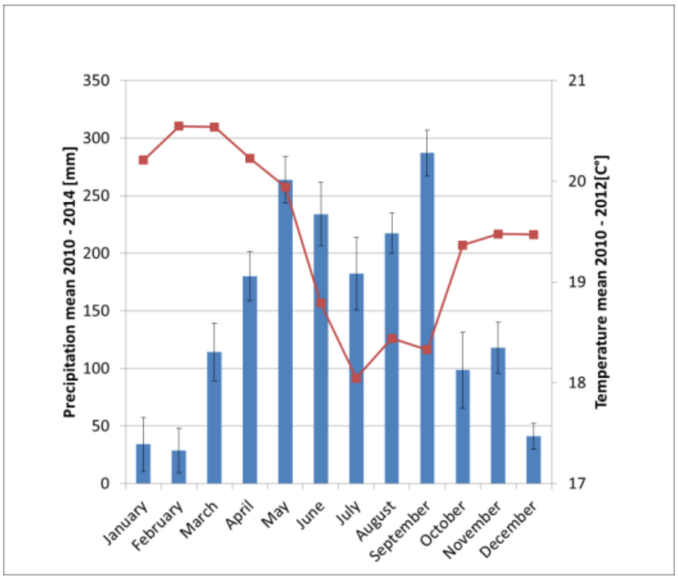
b. Climate

The climate data was taken at 1,800 m.a.s.l. by the meteorology station Wushwush (36°7'35,2"E 7°20'7,07"N). The climate conditions can be adopted for all study sites but local variations can occur, especially due to different vegetation cover (evaporation) and soil types (infiltration). Climate data, especially precipitation data, form the baseline information for all calculations concerning hydrology. It is advised to work on long-term climate data collation covering at least 30 years. But unfortunately, such information does not exist for the study area. Hence, all calculations are only an approximation.

The mean annual rainfall within the Kafa Biosphere is around 1,800 mm. According to the precipitation data of the Global Precipitation Climatology Centre (GPCC http://gpcc.dwd.de), the Kafa Biosphere Reserve has more than double the mean annual precipitation level of Ethiopia (812.4 mm). Temperature ranges between 18.05°C and 22.55°C with an annual mean of 19.45°C.

The following table shows the mean monthly precipitation values between 2010 and 2014 (until March) and temperature values between 2010 – 2012.

Figure 3: Climate data (Precipitation [mm]; Temperature [C°]) of weather station Wushwush



In May, the first precipitation peak is recorded and temperatures are still above the annual mean temperature (19.45 C°). Though precipitation is decreasing in June and July, it stays far above the monthly mean precipitation (150.03 $mm^{-1}month$). Two thirds of the annual precipitation occurs between May – September, whilst temperature values are lowest during these months (mean 18.71 C°).

According to the Köppen climate classification[3], the Biosphere Reserve falls in the main group of equatorial (A)[4], with the sub-classification of Monsoon Rainy with short dry winters (Am)[5].

To at least give an impression how much precipitation is potentially available for groundwater renewing, we used the empirical model after Turc(Turc 1961). Not included in the equation is the water consumption for agriculture and livestock. According to interviews in the study sites(Dresen 2014), the use of wells is not common (1.5% of questionnaired persons are using a well, n=130).

[3] Not based on the recommended timeframe of 30 years
[4] temperature average of 19.45°
[5] Annual precipitation less than 5x precipitation threshold

Hence, most human activities rely on surface water (except towns). Furthermore, it is assumed that the evapotranspiration in the study area is higher than after Turc (model developed for northern Africa), due to higher vegetation cover. The water balance is the baseline for verifying the in-/ outflow and to come up with a rating of the real water supply within the Kafa BR.

Water Balance: Q = P - EVT

With Q = mean annual run off, P = mean annual precipitation [mm/yr], EVT = evapotranspiration

The mean annual run off includes surface, intermediate and subsurface run off. The run off data from the draining ditches are unknown thus a distinction between them was not possible. The surface run off is influenced by the morphology and drains respectively into surface waters or wetlands. A part of the surface and intermediate run off is removed by the receiving water courses from the drainage basin. Another part flows delayed to the draining ditch as seepage water. A small share, the subsurface run off, percolates and participates in the groundwater recharge(Shiklomanov et al. 1990). Hence, the effective groundwater recharge is below the calculated mean run off.

Evapotranspiration consists of evaporation from the surface and active transpiration from vegetation. In terms of hydrologic modelling, it is distinguished between actual and potential evapotranspiration. Most common is the “PENMAN-Monteith” model to calculate the potential evapotranspiration. Due to very limited climate input data a more generalized model had to be used (TURC) to calculate the mean annual evapotranspiration (calculation see: Table 22).

$$\text{EVT after TURC} = P / \surd\,(0.9 + (P^2/ L(t)^2)\ [\text{mm/yr}]$$

Where, L(t) is the “evaporation capacity” = $300 + 25\,t + 0.05\,t^2$

T = mean annual temperature [°C]

Equation t for each month:

t mean = (tmax - tmin) /2

Table 1: Water Balance in Kafa BR (after TURC)

Year	2009/10	2010/11	2011/12
P [mm/yr]	1,151.99	1,776.81	1,670.4
EVT [mm/yr]	843.95	1,037.85	965
Q [mm/yr]	308.04	738.96	705.4

The year 2009/10 shows 50% lower values (308.04 mm/yr) of mean annual run off than the following years (>700 mm/yr). Due to a very small data time frame, conclusions cannot be drawn because errors in measurement are likely or just by incident a year with weather anomaly was captured. But these results show the importance of continuous climate measurements to be able to interpret these outliers in a correct way.

According to the questionnaires(Dresen 2014) and expert interviews[6], the water table in all pilot sites (Gojeb, Alemgono, Chidi wetland) lowers from year to year. One reason could be a higher surface run off to the draining ditches caused by a declining vegetation cover. Another reason could be the higher water consumption for irrigation of agricultural lands, for instance.

[6] Conducted by M. Dresen and W. Woldemariam at MoARD

PART 2 - Rivers

3. Classification of rivers within Kafa Biosphere Reserve on regional level

A community of streams shows various characteristics. For classification purposes only the most important ones are selected and evaluated. We focused on a few parameters to simplify the natural variability that exists in rivers, but provide sufficient information to characterize stream types and generate a good baseline for management decisions. Within the context of wetland protection, maintenance and sustainable management, rivers with specific importance are evaluated and recommendations for conservation action are formulated.

Source data for all analyses are the Digital Terrain Model (DTM) (Dresen, 2014), attributive information of the topographic maps are from the Ethiopian Mapping Authority (EMA), SPOT5 satellite imagery for actual spatial location, and field visits.

According to the Ministry of Water and Energy (MoWR)[7], the Kafa Biosphere Reserve forms part of the River Basins Omo Gibe (63%) and Baro Akobo (37%). Generally, a river basin[8] is the land area that drains precipitation into a particular stream or river system and can be delineated by a boundary (the watershed) following the ridge lines(Gold et al. 2005). This hydro-geographical boundary can be calculated on different scales, e.g. on a very local scale, the sub-basin to estimate the land which feeds single wetlands for example or on national scale to divide the area of a country with more or less closed flow patterns of materials and component substances.

The Omo Gibe river basin has an area of 77,744 km², covering parts of SNNPR and Oromia. The Baro Akobo river basin covers an area of 75,147 km² and is fed by the rivers of Benishangul-Gumz, Oromia, Gambella and SNNPR. According to the Ministry of Water and Energy, Omo Gibe river basin has a mean annual outflow of approximately 16.6 BMC (Billion Metric Cube)(Richard Woodroof & Associates 1996), while the total mean annual outflow from Baro Akobo river basin is estimated to be 23.6 BMC(ULG Consultants 1997). Due to the high mean annual flow from the river basins and a comparably low population density in SNNPR, both river basins but especially the Baro Akobo river basin, are of interest for large-scale irrigation(Awulachew et al. 2007).

The Gojeb river system, one of the pilot sites in this assessment (dominating Woreda Gewatta; with headwaters in Gesha and Bita) is contributing with significant outflow to the drainage system of Omo Gibbe. According to the main rivers listed (Ministry of Water and Energy), other important contributors are Guma/ Dincha river system (Bonga to Cheta), Adiyo river system (Adiyo Woreda), and Uda river system (headwaters in Bita Woreda).

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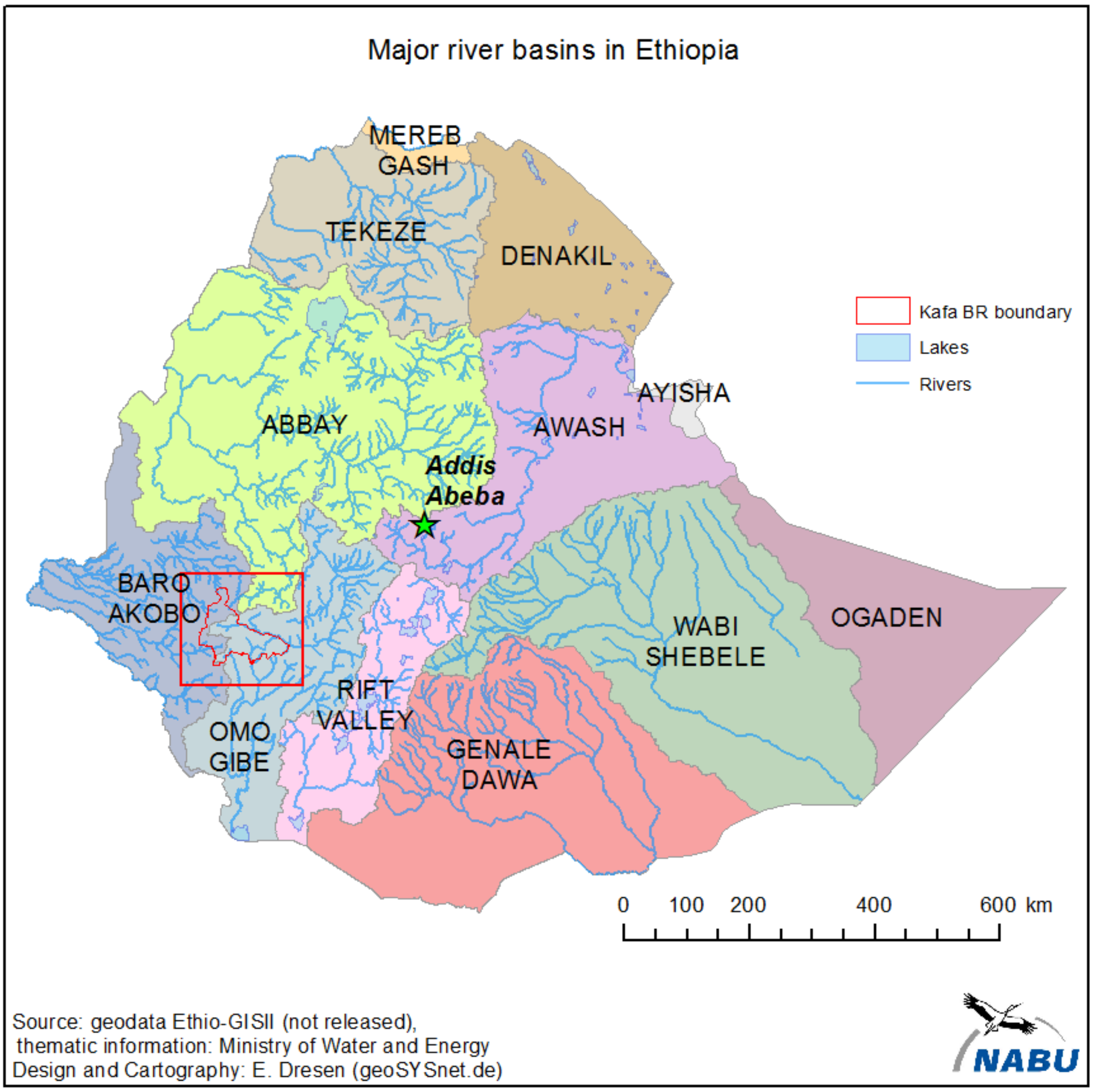
[7] http://www.mowr.gov.et/index.php?pagenum=3.1; visited on 12.12.2014

[8] Also known as catchment area, drainage basin, or catchment basin



Map 2: Major river basins in Ethiopia

Methods

After the digitalization of rivers from the Ethiopian Mapping Authority topographic maps (gathered, georeferenced and verified; see(Dresen 2009), all rivers were attributed when information was accessible, with names, width, velocity, depth, and type. Due to missing metadata, hence unclear application of methods, this information was only used as reference[9]. Furthermore, river courses were manually updated and artefacts corrected[10] by using actual SPOT5 satellite imagery (2011). Based on the DTM, geometric information was calculated. To be able to cartographically display the

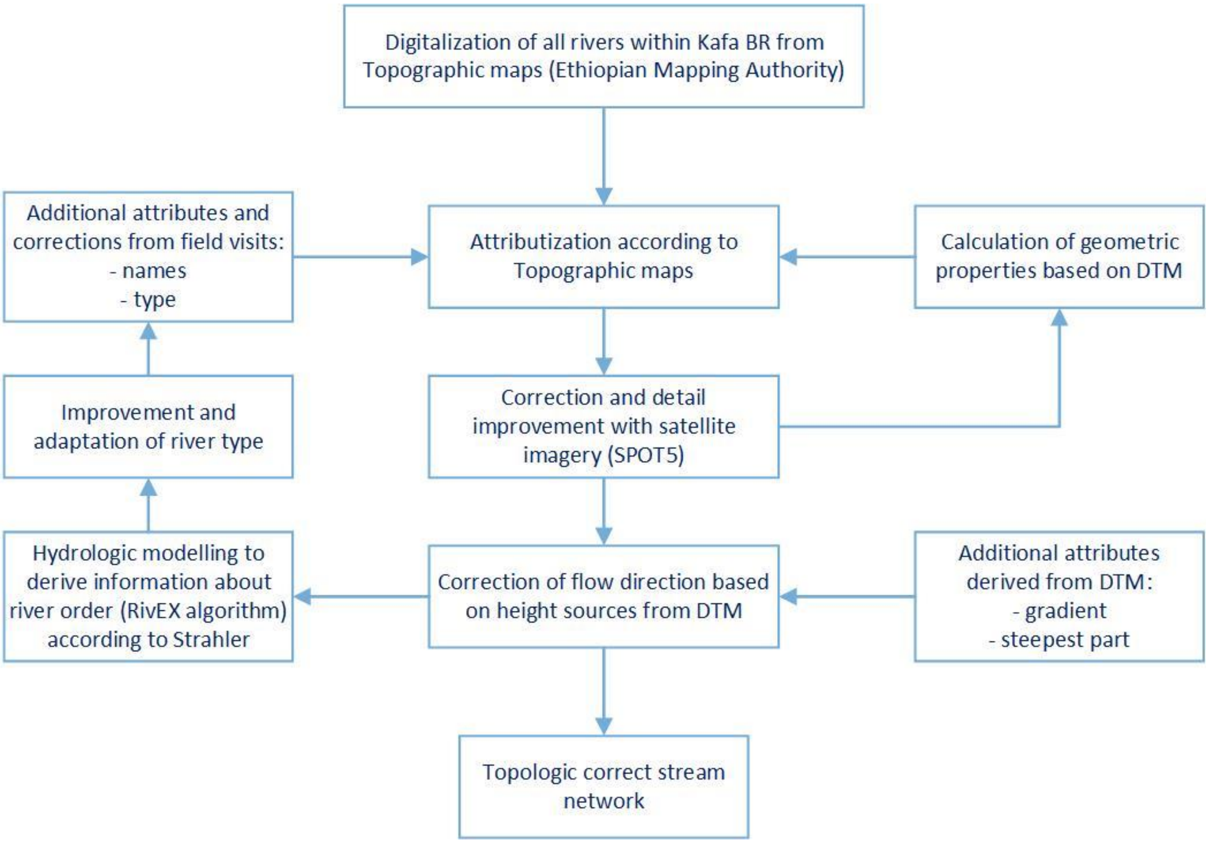
[9] The information of river names is used as primary data source and integrated into the cartographic display.

[10] Some problems occurred due to different topographic map sets (e.g. 0736C1/ETH4 year of production 1989; 0736C2/ETH4 year of production 2001). In some cases rivers were not continuous whilst rivers were missing in others. To overcome this problem, all streams occurring on different map sets were manually corrected according to satellite images.

flow direction, the start and end point of rivers were attributed with height information from the DTM and the line direction was adopted.

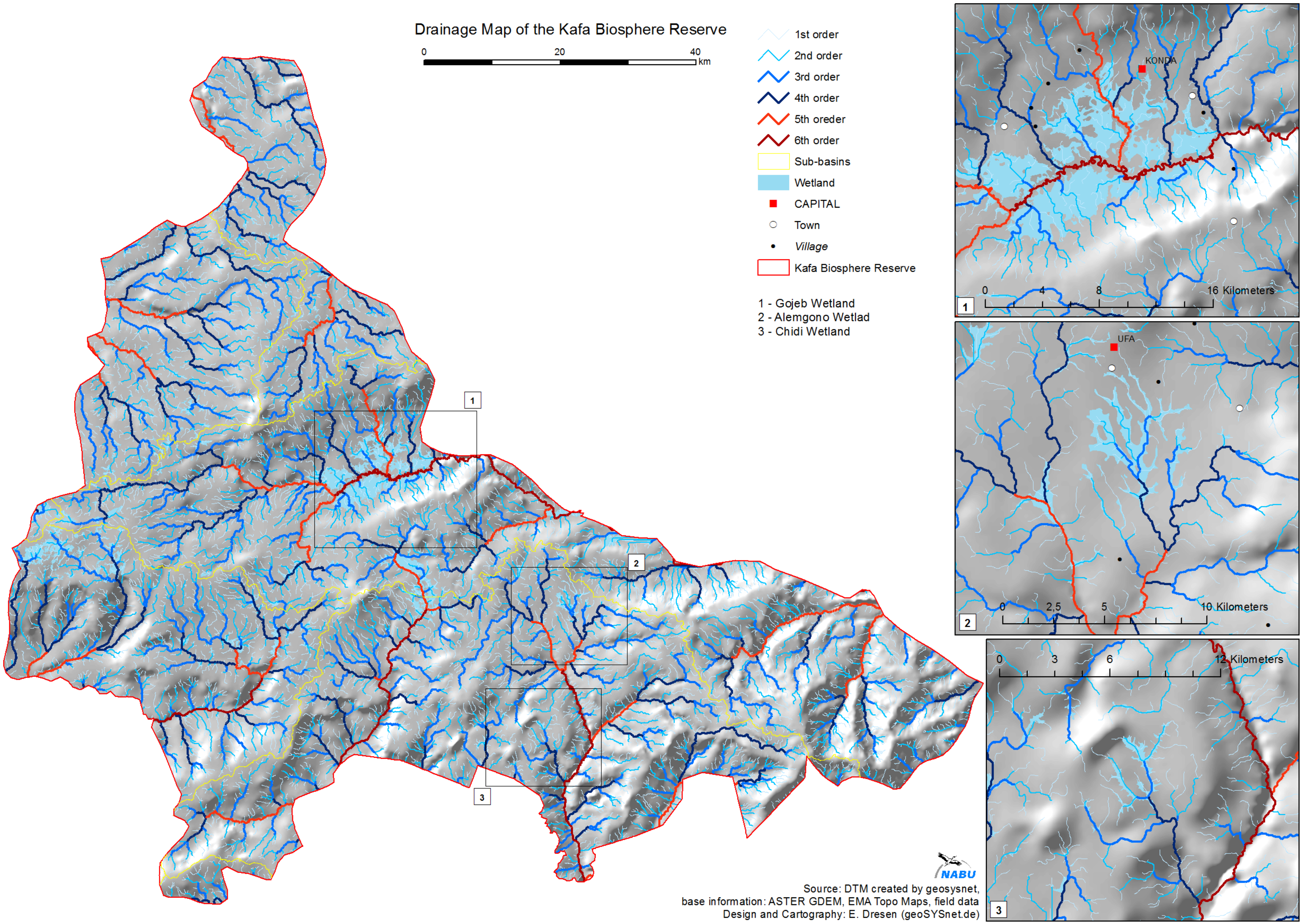
The full work flow to design a topologic correct stream network can be found below (Figure 4).

Figure 4: Flow chart for stream network creation



a. Drainage Network – Stream Order

For an appropriate water management and the characterisation of streams, the knowledge of stream order is necessary(Pradhan 2012). Physical and biological changes occur in streams from the headwaters to downstream sections. By knowing the order of streams, some ecological descriptors can be derived from the streams order. Hence, this is one of the main parameters used for classification. For example, headwater streams support fewer fish species than main streams because certain habitats are not frequently present. Additionally, the headwater streams are likely to have a higher flow velocity because they arise at steep terrain, which in consequence affects the oxygen content (mostly seen as a limiting factor for many species). When calculating Strahler stream order (Strahler 1957), headwater streams are assigned a 1 for first order streams. When two first order streams join, a second order stream is formed. Similarly, when two second order streams join, a third order stream is formed. Order numbers continue to be assigned throughout the drainage network (Tarboton et al. 1991). According to the Drainage network (Map 3) of Kafa Biosphere reserve, there are no strong lithological discontinuities. Most drainage patterns are dendritic and streams are more or less equally distributed.



Map 3: Drainage Map of Kafa Biosphere Reserve

b. Morphometric parameters of rivers

Quantitative analyses of morphometric parameters are used to explain geologic structures that may control the river system in a river basin (Moges & Bhole 2015). Beside the determination of stream order to rivers, there are additional morphometric parameters which are commonly used to describe the drainage basin and might give explanations for hydrological processes.

Stream length is one of the most significant parameters to reveal surface run off. Longer length indicates a flat gradient while smaller lengths are present on steep slopes.

The bifurcation ratio is seen to be an index for surface structure and dissections(Horton 1945). It can be obtained by dividing the number of streams in one order by the number in the next higher order. The index is dimensionless and ranges from 3.0 to 5.0 with modal values around 4 in areas without geological structures distorting the streams (Strahler 1957).

Stream length ratio is the ratio between the mean length of an order to the next lower order and usually ranges between 1.5 and 3 with a modal value of 2.

Table 2: Bifurcation Ratio, Stream Length and other morphometric parameters

Order of Stream	Number of Streams*	Bifurcation Ratio	Total Stream Length [km]	Average Stream Length [km]	Length Ratio
I	6,057		5,407	0,89	
II	1,350	4,49	2,731	2,02	2,27
III	338	3,99	1,324	3,92	1,94
IV	98	3,45	796	8,12	2,07
V	25	3,92	289	11,56	1,42
VI	4	6,25	167	41,75	3,61
Σ	7,872		10,714		
Ø		4,4	1,4		2,26

* a slight overestimation might be possible due to the study area, where the same river crosses in and out

c. Geomorphic characterization

The purpose of delineating rivers according to their longitudinal profile is to integrate the landform and fluvial features of valley morphology with channel structure. The parameter gradient to determine the longitudinal profile was calculated for every stream segment, while relating the mean slope of the DTM to each line. The classification is done according to Rosgen(Rosgen 1994) determining the longitudinal profiles.

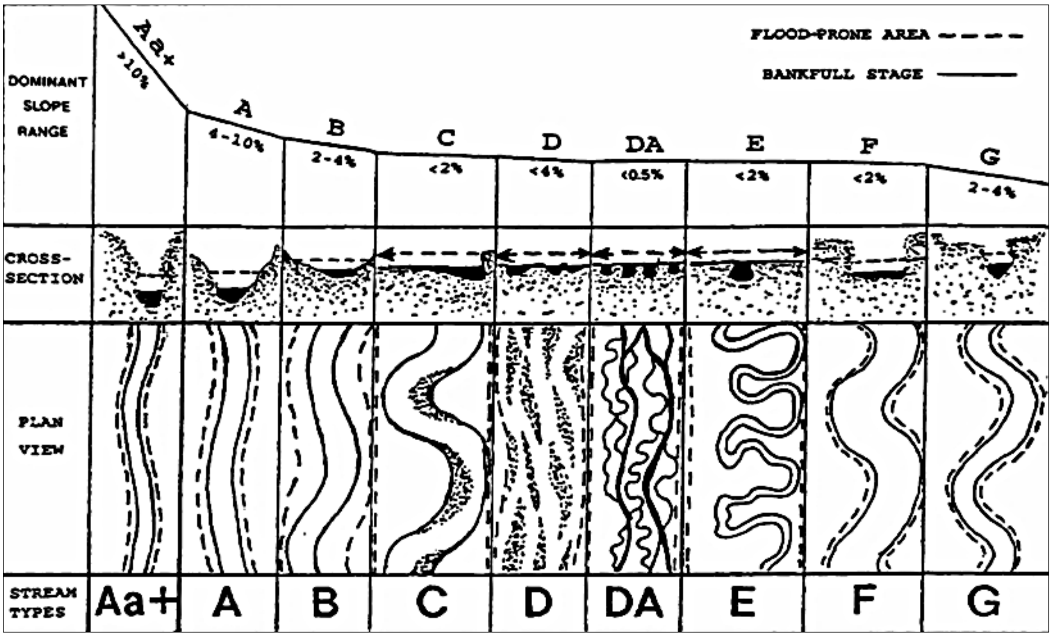


Figure 5: Longitudinal, cross-sectional and plan views of major stream types (taken from Rosgen, 1994)

Table 3: Summary of delineative criteria after ROSGEN (1994)

Stream type	General description	Slope [%]	Landform/ soils/ features
Aa+	Very steep, deeply entrenched, debris transport streams	>10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with/deep scour pools; waterfalls
A	Steep, entrenched, cascading | high energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel	4 –10	High relief. Erosional of depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step-pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks	2-3.9	Moderate relief, coluvial deposition and/ or residual soil. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with occasional pools.
C	Low gradient, meandering, point-bar, riffle/ pool, alluvial channels with broad, well defined floodplains	<2	Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology with high W/D ratio.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	<4	Broad valleys with alluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, with abundance of sediment supply.
DA	Anastomosing (multiple channels) narrow and deep with expansive well vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosity. Stable stream banks.	<0.5	Broad, low-gradient valleys with fine alluvium and/ or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition with well-vegetated bars that laterally stable with broad wetland floodplains.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander with ratio.	<2	Broad valley/meadows. Alluvial material with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	Entrenched meandering riffle/pool channel on low gradient with high width/depth ratio.	2	Entrenched in highly weathered material. Gentle gradients, with a high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	Entrenched "gulley" step/pool and low width/depth ratio on moderate gradients.	2 – 3.9	Gulley, step-pool morphology with moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials; i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

We assigned all rivers to the geomorphic classification after Rosgen (1994) according to their slope gradient and can summarize the following for the whole Kafa BR.

Table 4: Geomorphic characterization after Rosgen (1994)

Stream type after Rosgen	length [km]
A	5,903.4
Aa+	3,626.9
B, D, G	714.2
C, E, F	439.01
DA	132.6

Given that the Kafa Biosphere Reserve is situated in a mountainous area, it becomes obvious that the majority of streams are stretching over steep slopes (type Aa+ and A). Their erosive potential is high and they tend to transport debris and associated deposit of soil. The group C, D, DA, and F represent rivers following over low gradients, associated with different stream features like oxbows and meander scars. Solely present in this group, are rivers of 5th-6th Strahler order and often in association with floodplains and alluvial soils. Though, the group B, D, G has very different plain views, they are associated with colluvial pedogenesis.

d. River flow type (flow regime)

Rivers are either “perennial” or “non-perennial”, whereas non-perennial rivers can be further distinguished between “seasonal” and “intermittent”.

Due to the seasonal rainfall patterns, it is necessary to distinguish between rivers that flow continuously throughout the year, which we refer to as perennial river, and rivers with water flowing for extended periods during the wet season (mostly between April – October) but not during the rest of the year, and intermittent streams, with water flows for a relatively short time (< 3 month) and intervals varying from less than a year to several years.

Table 5: River flow type in Kafa BR

River Flow Type	Length [km]
intermittent	6,680
perennial	3,860
seasonal	275

The persistence, frequency, duration and volume of intermittent streams can be particularly influenced by management interventions (Bond & Cottingham 2008). Drivers, improvable by small-scale measures, are land use, riparian condition, and water extraction. A (probably very) local phenomenon is the stock movement on intermittent streams, which leads to substantial erosion.

According to in-depth interviews, the most important service from intermittent streams is water extraction for domestic use and livestock water supply, as well as sometimes for hand irrigation (e.g. in tree nurseries and home gardens).

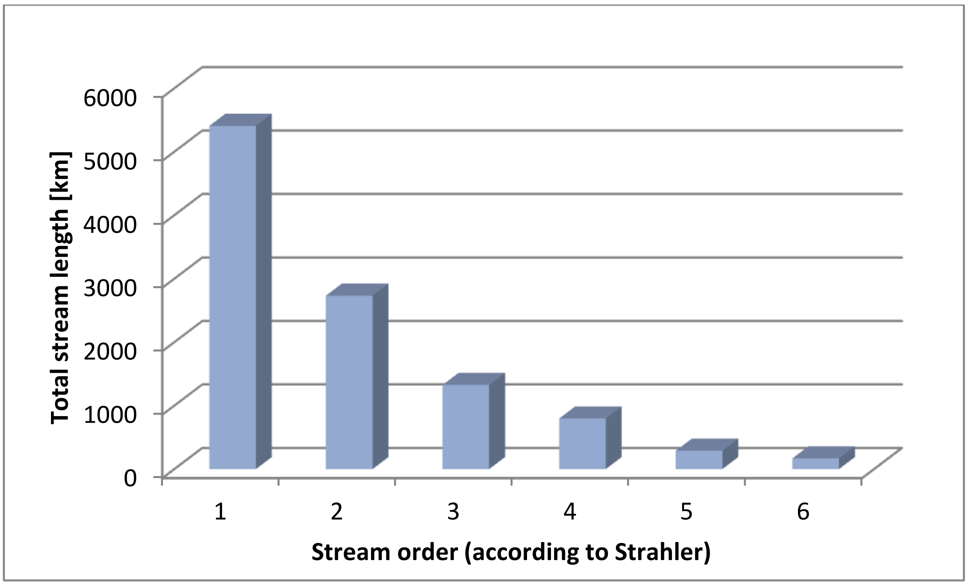
Figure 6: Intermittent stream erosion through stock movement (35°58'39,721"E 7°34'35,84"N | photo W. Woldemariam)

e. Results of river descriptive parameters and recommendations

Stream order in the whole Kafa BR is of 6th order. This class is only formed by 4 rivers: Gojeb river (south of Konda), Meni river (east of Bita Genet), Woshi (Weshi) becoming Sherma river (starting 10 km west of Wushwush, passing Dimbra), and Dincha becoming Guma (Gumi) river (passing Bonga). Only a quarter of all rivers feed the river Basin Baro Akabo, while 8,570 km drain to the Omo-Gibe basin.

Quantitatively, most rivers in the Kafa Biopshere Reserve are of 1st and 2nd order (**Fehler! Verweisquelle konnte nicht gefunden werden.**). These are the streams that flow into larger streams but do not normally have any water flowing into them. In addition, 1st and 2nd order streams generally form on steep slopes and flow quickly until they slow down and meet the next order waterway. 1st to 3rd order streams are also called headwater streams and constitute any waterways in the upper reaches of the watershed.

Figure 7: Stream length versus stream order according to Strahler and length [km] within the Kafa BR



Every stream with an order higher than 4, is globally seen as a medium river (the Amazon is 12th order). These rivers are usually less steep and flow slower. They do however tend to have larger volumes of run off and debris which collects from smaller waterways flowing into them.

In the Kafa BR 76% (1st and 2nd order) of all waterways are headwaters, 12% are classified as streams (3rd order), and 12% are rivers (> 3rd order). Headwaters are of particular importance as water source for wetlands. The importance of lateral surface inflow via channelled streams differs from one wetland to another. If a perennial inflow exists, it normally contributes significantly to the wetlands' water regime. Such streams fall within category (A), while "have(ing) a specific importance concerning the hydrology of a wetland" (Andersson & Nyberg 2009).

#1 Recommendation:

Headwaters contributing to wetlands as major water source should gain a specific protection status.

The total stream length of all rivers within Kafa BR is 10,714 km of which streams, of the 1st order ones have a legth of 5,407 km (50%). It is a common finding that with increasing stream order the total length of streams decrease (Ali & Khan 2013). This is reversed in the average stream length. The mean stream length is increasing with the stream order. This can be generally observed in stream networks ("law of stream length" (Horton 1932)) and is related to the dependency of slope and stream order. The steeper the travel surface for streams, the shorter and straighter the stream segments, while streams in flat terrain tend to meander or form braided channels.

The stream length ratio ranges from 1.42 – 3.61. The stream length ratio between different stream orders shows high variation (Table 2). This indicates a high variation in slope and topography in general.

According to the bifurcation ratio, ranging from 3.45 up to 6.25 with an average of 4.4 (Table 2), strong structural disturbances have occurred in the basin when the underlying geological structure transforms from one series to another series. Accordingly, the pattern of streams are mainly influenced by structural factors(Moges & Bhole 2015). Furthermore, the bifurcation ratio is widely used to estimate the potential for flooding(Eze & Efiong 2010; Withanage et al. 2014; Pallard et al. 2008). Thus, if streams are highly bifurcated, flow is less concentrated so that flooding is a minor expected threat. The value range in the Kafa BR for bifurcation is with 2.8 relatively high(Gebre et al. 2015), which is a result of the high bifurcation ratio between streams of 5th and 6th order. This shows that numerous tributaries drain into relatively few trunk transporting stream segments. Consequently, the main rivers in the Kafa BR (Gojeb river, Meni river, Woshi river, Dincha river) are prone to flooding, which leads to a waterlogged periphery. A vital corridor of forest can benefit from temporal inundation and foster specific conditions for various species. Especially, rivers belonging to the stream type C, D, DA (after Rosgen; Table 4) have wide river benches mostly associated with alluvial soils. These nutrient rich and dynamic habitats have an outstanding value in terms of biodiversity and hydrology.

#2 Recommendation:

Maintain, restore, and re-establish a vital riparian forest buffer along the main rivers in Kafa BR (6th order, stream type, C/D, perennial).

The drainage pattern in Kafa BR can be described as dendritic, where tributaries join at an acute angle and sub-parallelly, where river segments appear almost in parallel, catchments are elongated, and tributaries join at a small acute angle. According to Dhokrikar(Dhokrikar 1991) the development of dendritic drainage is associated with the areas of lithology and gently sloping to almost horizontal or flat topographic surfaces having extremely low relief. In some cases, it does not follow the pure dendritic pattern where tributaries of various orders and magnitudes resemble branches of a tree joining the trunk. Often we can observe also a sub-parallel type of drainage pattern, which is caused of the steep topography(Babar 2005).

The parameter drainage density[11] is recognized for understanding landscapes because it is closely linked to "*hydrologic processes including infiltration, soil saturation, sheet erosion, overland flow, and*

[11] The drainage density is defined as the cumulative length of all streams divided by the area (Horton 1945)

their interactions that control the production of runoff and sediment"(Moglen et al. 1998) and can show the links between climate and topography. A high drainage density reflects a highly dissected drainage basin with a relatively rapid hydrologic response to rainfall events, while a low drainage density means a poorly drained basin with a slow hydrologic response(Yildiz 2004). But since drainage density is not a simple function of precipitation, but an expression of the interrelationship of climate, soil geology, and vegetation, interpretation is complex and rather difficult. Compared to a study from Tigray, Ethiopia(Gebre et al. 2015) with a drainage density of 1.7 km/km², the drainage density within Kafa BR with 1.8 km/km² is quite similar. Gebre et al (Gebre et al. 2015) describe the drainage density as a medium which "*indicates the presence of moderately resistant semi-permeable material with moderate relief*". Other studies found, that low drainage density (0.55 – 2.09 km/km²) results in areas of highly resistant rocks or permeable subsoil material, dense vegetation and low relief (Nag 1998; Withanage et al. 2014) and the higher the drainage density, the faster the runoff and the more significant the degree of channel abrasion for a given quantity of rainfall. According to Strahler(Strahler 1957), low drainage density leads to coarse drainage texture. Due to the fact, that in this analysis we account values for a study area and not for a single drainage basin, we are not able to calculate the drainage texture (numbers of rivers/ perimeter of drainage basin). For Kafa BR, a medium drainage density though having steep terrain (12.2° mean slope of terrain; Std.dev. 7.9) and high mean annual precipitation (1,800 mm) might indicate fairly good infiltration rates. The high share of forested area (47%[12]) in Kafa BR provides evidence for this.

Beside ecological functions, rives provide unique and essential services for all inhabitants in Kafa BR. According to the online questionnaire, the most important ecosystem service of rivers and wetlands is the supply of fresh water and water retention function, respectively (Figure 18). Cities have a particularly high water demand and social welfare is closely linked to the provision of fresh water for domestic supply. We assume that all perennial rivers, intersected with towns and cities, contribute to a significant share of the water consumption. Consequently, those rivers have to be maintained in a good ecological condition. Bearing in mind that higher order streams accumulate all deposits from agriculture, additional natural water purification measures should be undertaken in areas with high application of fertilizer and/ or agrochemical (i.e. vegetation buffer along stream).

Within the Kafa BR, 61% of all streams are of intermittent nature. 36% are perennial streams and 2% are seasonal streams. To maximize the benefit of fresh water for as many people as possible, influencing factors that degrade water quality or lessen the amount of water can be improved. In general, mountainous rivers with a high width/ depth (W/D) ratio when fully exposed to solar radiation have very high evaporation rates. According to Rosgen (1994) rivers of type C and F have especially high W/D ratios. If riparian forest exists, efforts should be undertaken to maintain and restore the forest buffer.

[12] According to own analysis on SPOT data 2011(Dresen 2011)

#3 Recommendation:

Rivers contributing to the fresh water supply of town and cities should be framed by a forest buffer.

Rivers, passing through a matrix of intense agriculture on moderately steep terrain are prone to non-point source pollution (high intake of fertilizer and agrochemicals). Efforts should be undertaken to minimize the surface run-off from intense agriculture. Small-scale measures are intercropping within an agroforestry system, to build up contour stripes with stones (hedgerows) and in general, promote a site-adopted sustainable fertilizer application.

#4 Recommendation:

Rivers embedded into a wide agricultural matrix and situated in steep terrain are prone to degradation. To maintain or improve water quality, surface run-off should be minimized and a wise use of fertilizer should be promoted.

f. Results and spatialization of recommendations

All results are presented as spatial data (.kml) and tabular extracts in the Appendix. Due to the low map scale of the Kafa Biosphere Reserve, the cartographic representation was not adequate to portray, i.e. small river segments. All semi-automated products should be verified in the field and management implications discussed with local communities. The recommendations formulated in 3.e address rivers that:

(A) Have a specific importance concerning the hydrology of wetlands,
(B) Have a high contribution to social welfare,
(C) Are susceptible to degradation and should gain specific attention.

(A) Depending on the contribution of rivers as water sources for wetlands, some rivers have specific importance towards wetland protection. Especially if the wetlands are mainly fed by rivers (instead of groundwater or precipitation) or the water regime of a wetland is mainly dominated by the river dynamic (seasonal and occasional inundations, e.g. floodplains), wetland protection should include the contributing river. This issue is addressed under the recommendation #1. For spatialization and giving a reference within the Kafa BR, all headwaters (stream order 1 and 2) connected to wetlands were selected and intersected with wetlands having lateral surface flow as main water. The semi-automatically computed product should be cross-checked with field visits. The selection does not imply that there is a need for urgent action. The spatial dataset is named "River_protection_source_for_wetlands.kmz". The tabular result can be found in the Appendix (Table 24).

(B) Rivers, constituting the main water supply for downstream population should gain specific protection status. This issue is addressed under the recommendation #3. For spatialization, all medium rivers (> 3rd river order) passing (< 1.5 km distance from a city centre) urban areas (towns, Woreda capitals) are selected as rivers of concern. The spatial dataset is named "River_protection_domestic_water.kmz". The tabular result can be found in the Appendix (Table 25).

(C) There are some types of rivers which are more exposed to non-point source pollution than others. For example, first-order streams are dominated by overland flow of water; they have no upstream concentrated flow. Because of this, they are most susceptible to non-point source pollution problems. Furthermore, rivers situated in a steep terrain embedded into a matrix of agriculture are found to be additionally threatened and included into the spatialized recommendation. This issue is addressed in recommendation #4. Measures include wide riparian buffers, contour strips and a low application of fertilizer. The selection includes all stream segments, which are fully enclosed by agriculture.

The spatialized recommendations should be understood as a basic guideline for the integrated management of aquatic ecosystems but not as a modus operandi.

PART 3 - Wetlands

4. Classification of wetlands within Kafa Biosphere Reserve on regional level

In general, all wetlands within the Kafa Biosphere Reserve belong to „wetlands of the western highlands – Keffa zone – ghibe and gojeb“ (IUCN, 2003).

The developed classification of wetlands within Kafa is adapted to the straightforward management and linked to management suggestions. The classification according to the ecological condition, the potential threats and the importance of the wetland results in recommendations. All contributing factors can be found in Figure 2. To give a baseline for evaluation, also vegetation and soil is described in the following sections.

a. Vegetation

Dominant plant species were determined during the field visits in the three pilot sites. These dominant plant species are grouped to map units according to their abundance and percentage cover (described in Chapter 5). Spatialization of the vegetation units or map units, can be found in Map 14, Map 20 and Map 25 .

For the regional classification, the landscape matrix (Land Use/ Land cover) was used to identify the state of naturalness (Chapter 4.c). Auxiliary parameters collected from key informants (unique landscape settings, like wetlands with vast riparian bamboo vegetation) are integrated.

Figure 8: *Cyperus latifolius* (photo by C. Tegetmeyer)

Cyperus latifolius (local name: Koho), a robust perennial with sharply three-angled culms up to 160 cm height and up to 250 cm long leaves, with scabrid margins and midrib, belongs to the Cyperaceae and is widespread in Africa and Madagascar(Hedberg & Edwards n.d.). It occurs under wet soil conditions and can build >2 m high impenetrable thickets, but also occurs in looser and shorter stands on pastures, where it is eaten by cattle. It has been found in every investigated wetland in dominate stands (compare(EWNRA 2008)) and it is often used for roof thatching by the local farmers. The species is not mentioned in the management plan of the Gojeb wetland (EWNRA 2008), because the floristic survey was not complete.

Figure 9: *Cyperus denudatus* (photo by C. Tegetmeyer)

Cyperus denudatus, an approximately 100 cm high perennial Cyperaceae, with three-angled culms, is widespread in tropical Africa and occurs on swamps and other wet habitats(Hedberg &

Edwards n.d.). The species is not mentioned in the management plans of Alemgono and Gojeb wetland(EWNRA 2008). It was found in Chidi and Alemgono Wetland on waterlogged peat soil, often in company with Thelypteris confluens.

Figure 10: *Schoenoplectus corymbosus* (photo by C. Tegetmeyer)

Schoenoplectus corymbosus is a robust perennial Cyperaceae. Stems grow to a maximum height of 300 cm, leaf blades are absent. The inflorescence consist of a lax anthela with clusters of spikelets on unequal branches habitats (Hedberg & Edwards n.d.). The species is not mentioned in the management plans of Alemgono and Gojeb wetland (EWNRA 2013), nor in the Kafa Wetland Report (EWNRA 2008) and was maybe confused with the very similar *Schoenoplectus confusus*. After Hedberg and Edwards (1989-2009) the inflorescence bract of *Schoenoplectus corymbosus* is shorter as the inflorescence itself, as it was observed in the field. It occurs in wet habitats with standing water like swamps, pools, lake margins in tropical and South Africa as well as Madagascar. It was found in Chidi and Alemgono Wetland on waterlogged peat soil often in company with *Thelypteris confluens* and *Cyperus denudatus*.

Hyparrhenia dregeana is a Poaceae. It is a very high growing culm with a characteristic inflorescence which reaches a height of 300 cm, whereas the leaves length reaches only 40 cm. The species builds high hummocks and occurs on peat and on seasonally wet mineral soil in Alemgono and Gojeb Wetland. Presumably the species is grazed by cattle although grazing was not observed during the field work. The species is neither mentioned in the management plans of Alemgono and Gojeb wetland (EWNRA 2013), nor in the Kafa Wetland Report (EWNRA 2008).

Figure 11: *Hyparrhenia dregeana* (photo by C. Tegetmeyer)

Arundo donax, a 200 - 600 cm tall perennial grass which is not flowering in Ethiopia (Hedberg and Edwards 1989-2009), is commonly known as Narhal/ Arundo grass/ giant reed/Giant cane/ Carrizo/ Spanish cane, wild cane (Lansdown 2015). It occurs on wet soils close to rivers and was observed in Gojeb wetland. The species is described as very important grazing species in the Kafa Wetland Report (EWNRA 2008).

Figure 12: *Arundo donax* (photo by C. Tegetmeyer)

Thelypteris confluens is an approximately 100 cm high fern species, widespread in Eastern and Southern Africa(Hedberg & Edwards n.d.). The species is adapted to swampy areas and was frequently observed in the company of *Cyperus denudatus* on water-logged peat soils in Chidi and Alemgono Wetland. In the in the management plans of Alemgono and Gojeb wetland (EWNRA 2013), and in the Kafa Wetland Report (EWNRA 2008) one fern was mentioned, but without its scientific name, it is probably the same species.

Figure 13: *Thelypteris confluens* (photo by F. Mundt)

Figure 14: *Berula erecta* (photo by F. Mundt)

Berula erecta is an up to 200 cm tall perennial Apiaceae with leaves up to 50 cm long and leave opposed umbels with up to 20 white flowers, which is found in shallow water and in marshy areas. The species is widespread in Africa, Eurasia and North America(Hedberg & Edwards n.d.). *Berula erecta* is toxic and can cause death of grazing animals (De & Lansdown 2013).

Species of conservation concern

According to the IUCN Red List of Threatened Species 2014.3 (IUCN 2014), no threatened or endemic plant species occurs within the three pilot sites (Table 28: Species list with relevant indicators). Thus conservation activities cannot be derived directly from the presence of individual species. However, it should be noted that some species have a high ecosystem value for the local people and are a prerequisite for endemic fauna like the Rouget's rail (*Rougetius rougetii*), breeding in marshy areas with reeds and tussocks, that is classified as Near Threatened (NT) on the IUCN Red List (IUCN 2014) because of habitat loss caused by intensive grazing (BirdLife International 2012).

Biodiversity as indicator for the ecological condition, was not selected, because in some wetland types, biodiversity is naturally low and human interventions (e.g. application of fertilizer will improve the nutrition budget) will increase the diversity of communities and species in the wetland. Consequently, the number of species a wetland contains is not in itself a sufficient indicator of ecological condition. This phenomenon can be found e.g. in the Pilot site Chidi (Chapter 5.c).

b. Soil

According to the "Major landform map of Ethiopia" in Merla et al. (1979), the Keffa Zone is not influenced by distinct tectonic escarpements nor is it dominated by volcanos, canyons or faults (Abbate et al. 2015). Keffa Region is structured mainly by Pliocene acidic domes and plugs in the north of Bonga with traversal tectonic lines. A few huge rhyolite plugs and domes (e.g. Mt.Egan, Mt. Mizan Tafari) constitute a prominent and peculiar feature of the southern Ethiopian plateau. According to their relationships with the surrounding volcanites, they are doubtfully assigned to the Pliocene (Merla et al. 1979).

According to "The digital soil map of the world" at 1:5,000,000 scale (FAO 2014), the soil types of Kafa Biosphere Reserve are Eutric Nitosols and Eutric Cambisols. With a scale of 1:5,000,000 the soil map is far too imprecise to note regional and local soil characteristics as it would be necessary for this study. Thus we could not use the FAO classification. The pilot sites consist of hydromorphic soils partly mineral (Gleysols) and organic (Histosols) (IUSS Working Group WRB 2006).

Gleysols occur on slopes and stronger inclined areas. The substrate consists of fine alluvial material, like loam and clay and the occurring soil is strongly influenced by water. In Alemgono Wetland bog iron ore was found on groundwater influenced gley soils.

Histosols occur on even surface conditions in depressions and in wetlands located in valleys, often surrounded by elevations with steep slopes. The occurring peat consists of wetland plant roots and the decomposition degree shifts from moderate to high. In contrast to the Kafa Wetland Report (EWNRA 2008a) were Alemgono is considered as a wetland on "inorganic soil", we expect considerable peat stocks > 1 m in Alemgono and Chidi Wetland.

The pH value of all tested soils within the pilot sites alternate around 5, which indicates slightly acid conditions.

c. Classification of present ecological condition/ Hemeroby

The probable ecological condition of a wetland is classified on a qualitative scale ranging from ahemerob/"natural" to polyhemerob /"extensively modified" (Table 6). Due to the fact, that just few wetlands within the Kafa BR could be assessed concerning the degree of hemeroby, various auxiliary spatial parameters are applied and combined in a model. The model fitting is based on expert knowledge from online and key interviews, and compared with independently gathered data from the pilot sites. There are some limitations of the model, due to the different resolution of geodata[13] and the lack of additional data from soil, spatial variability in climate, information about flooding.

Table 6: Hemeroby - ecological condition of a wetland

Scale	Degree of Hemeroby/ Description	Example	Possible desirable features	Possible negative features
0	**Ahemerobic - Natural** Natural habitat and functions are unmodified	No human interaction	High biodiversity, habitat for rare species, natural hydrological functions	Source of disease (e.g. malaria), no natural resource exploitation available for local communities
1 +	**Oligohemerobic - Largely natural** Few modifications, A small change from natural habitats and biota may have taken place, but the wetlands "natural functions" are essentially unchanged	Small amount of human intervention (e.g. collection of construction material, collection of medical plants)	Communities livelihood benefit from natural resources and the extraction is sustainable	Source of disease
2				
3 -				
4 +	**Mesohemerobic - Moderately modified** A loss of and change from natural habitats and biota have occurred, but the basic	Some land-use change and/ or minor modification of natural hydrological regime	Some agricultural production supports some people's livelihood- Natural	Limited water control, so crops/livestock at risk from flooding/drought.
5				
6 -				

[13] Kebele level for TLU, population density; DTM raster resolution (30x30) for road density; 2.5 m for LULC and share of non-grazing areas, respectively; 2.5 m for hotspot analysis

	ecosystem functions are still predominantly unchanged		resource exploitation is still possible and sustainable	
7 + **8** **9 -**	**Euhemerobic - Largely modified** A large loss of natural habitat, biota and basic wetland functions has occurred	Significant land-use change and/ or significant modification of the natural hydrological regime	Agricultural production and/or intense grazing supports many people's livelihood	Significant reduction in natural resource exploitation, loss of beneficial hydrological functions, some soil erosion
10	**Polyhemerobic - Extensively modified** The loss of natural habitat, biota and basic wetland functions is extensive	Wetland ecosystem very significant altered from its perceived "natural" condition. For example extensively land-use change due to grazing or crop cultivation and highly modified hydrological regime (e.g. through drainage)	High agricultural production sustains many livelihoods	Massive reduction in biodiversity, loss of beneficial hydrological functions, possibly including pollution of water sources, soil erosion
" + " identifies those sites, which are found in a specific class but tend to be "more natural" than the mean of the class " – " identifies those sites, which are found in a specific class, but tend to be "less natural" than the mean of the class				

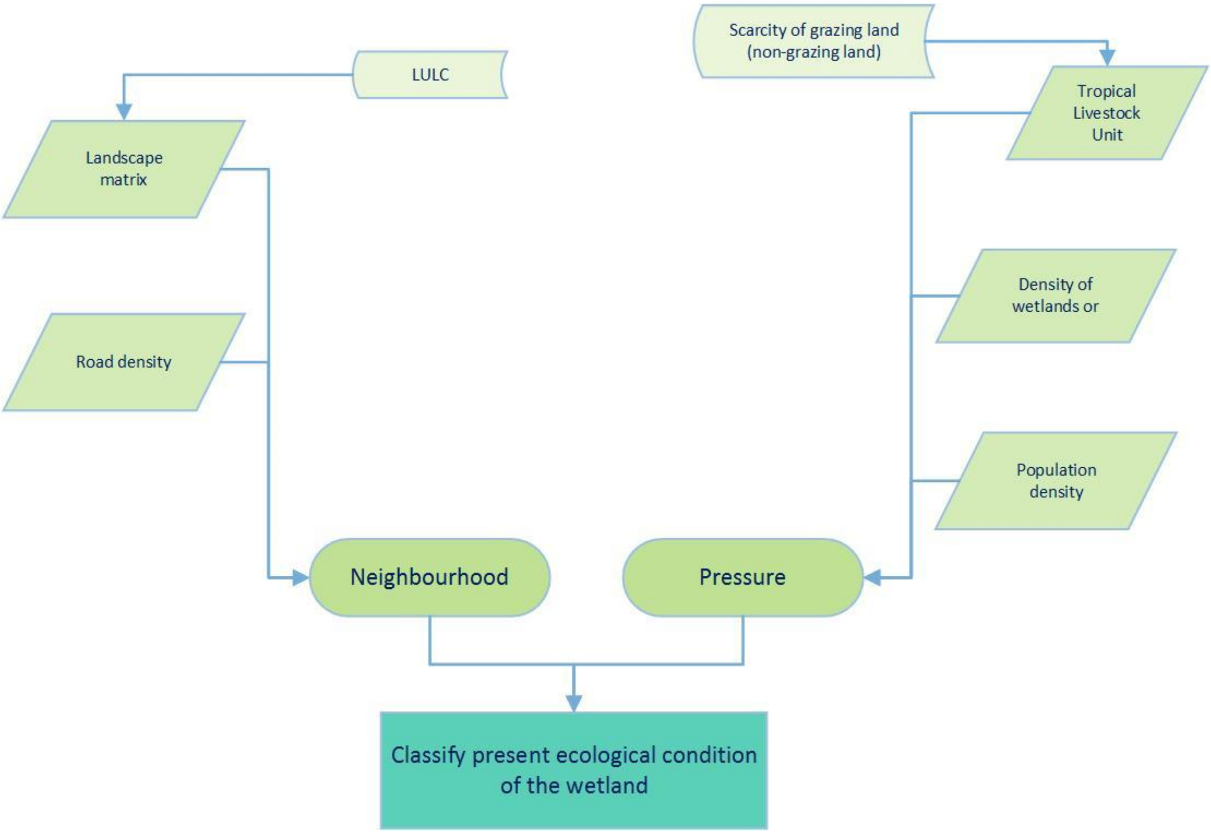


Figure 15: Flowchart of detemining the degree of hemeroby within Kafa BR

Generally, the degree of hemeroby in our model is influenced by two parameters.

The pressure on wetland resources with the descriptors population density, tropical livestock unit in relation to alternative grazing land and the spatial distribution of wetlands (assessed via hot/ coldspot analysis).

Furthermore, the present ecological condition is described by external factors, as the wetland is in a better condition when having a forested buffer, than wetlands surrounded by agricultural or urban areas(Tiner 2000). Descriptor for that is the landscape matrix. Accessibility is widespread known as a strong predictor of ecological condition and is implemented with the road density.

As not all descriptors of the ecological condition of wetlands have the same importance, we applied a weighted suitability and adopted all criteria according to expert knowledge gathered from interviews. The spatial model for assessing the ecological condition of a wetland can be found in the Appendix (Figure 52).

The results of the degree of hemeroby for all wetlands in Kafa BR are stored as geodataset "degree_hemeroby.kmz". The distribution of Hemeroby wetlands inherent looks as follows for the whole Kafa BR:

Table 7: Degree of hemeroby from wetlands within Kafa BR

	Degree of hemeroby	[ha]
artificial – naturalness	Oligohemerob +	2,451
	Oligohemerob	3,690
	Oligohemerob -	5,930
	Mesohemerobic +	4,843
	Mesohemerobic	4,469
	Mesohemerobic -	3,090
	Euhemerobic +	1,111
	Euhemerobic	172
	Euhemerobic -	1

It is important to note, that wetlands belonging to the class of polyhemerobic (extensively modified) or of ahemerobic (natural – without any human influence) are completely missing. This might be an indicator for the models' limitation, howbeit it is not expected that areas, which meet the MMU[14] (> 1 ha) are belonging to one of those classes.

The model seems to be able to predict tendencies, here briefly demonstrated at the pilot site Alemgono (ground thruth), which consists of very different ecological conditions, which are discussed in detail in Chapter 5.a.iv.

[14] The Minimum Mapping Unit is the smallest uniform area that is delineated during image interpretation and is determined from inspection of the image source. It was specified as 1 ha for a map scale of 1 : 50,000

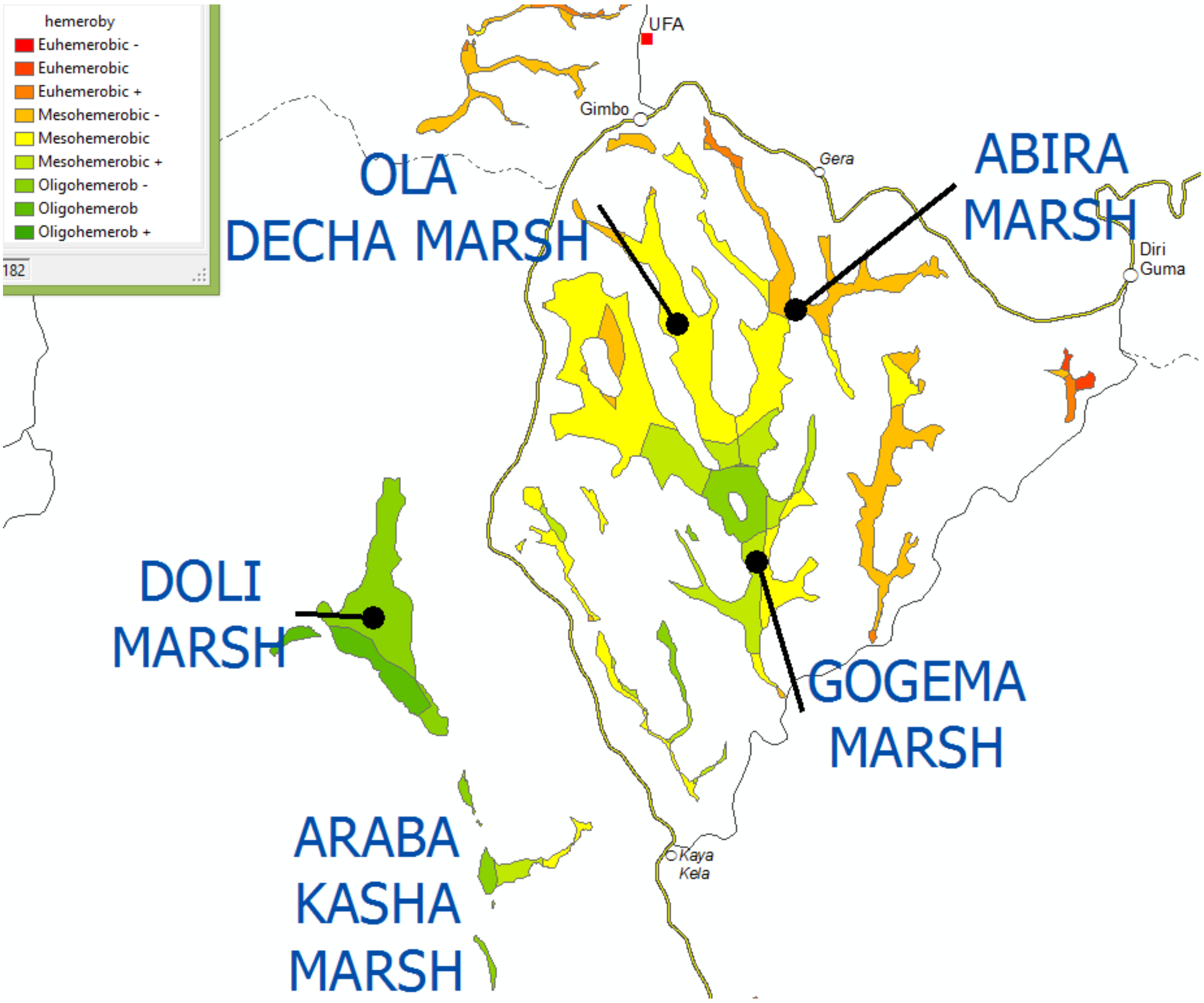


Figure 16: Example of the hemeroby model results (Pilot site Alemgono wetland)

The gradient, also found on the ground, from north to south with an ascending "naturalness" and a range from oligohemerob to euhemerob is realistic. Furthermore, the small reference wetland site west of Alemgono, Doli marsh, is difficult to access though it is close to the road network (which is a model descriptor for low naturalness) but the model result depicts a quite "natural" ecosystem, which can be confirmed from different field visits.

d. Classification according to threats

Tough wetlands are dynamic ecosystems with a different appearance according to the season, 65% of their change is the result of human action(Gebresllassie et al. 2014). As in most sub-Saharan Countries, the wetlands of the Kafa BR are under increasing threat(EWNRA 2008; EWNRA 2013) and the underlying reasons are common in African wetlands but complex. Population growth and climate change impose increasing pressure on wetlands and their beneficial functions. Additionally, the missing political framework and awareness to support a sustainable use of wetland resources in Ethiopia foster their over-exploitation.

According to Tekaligne (2003), direct threats can be categorized in physical, chemical or biological changes with different consequences for a vital wetland(Desta 2003). In this study, possible direct threats to the ecological condition of Kafa´s wetlands are compiled form literature, field observation, online survey or communication. Most of the criteria could be translated to spatial components which contribute to the multi-criteria analysis. Threats without geodata reference are taken into concern as recommendation. This is not a holistic threat analysis but an attempt to support conservation efforts and management strategies.

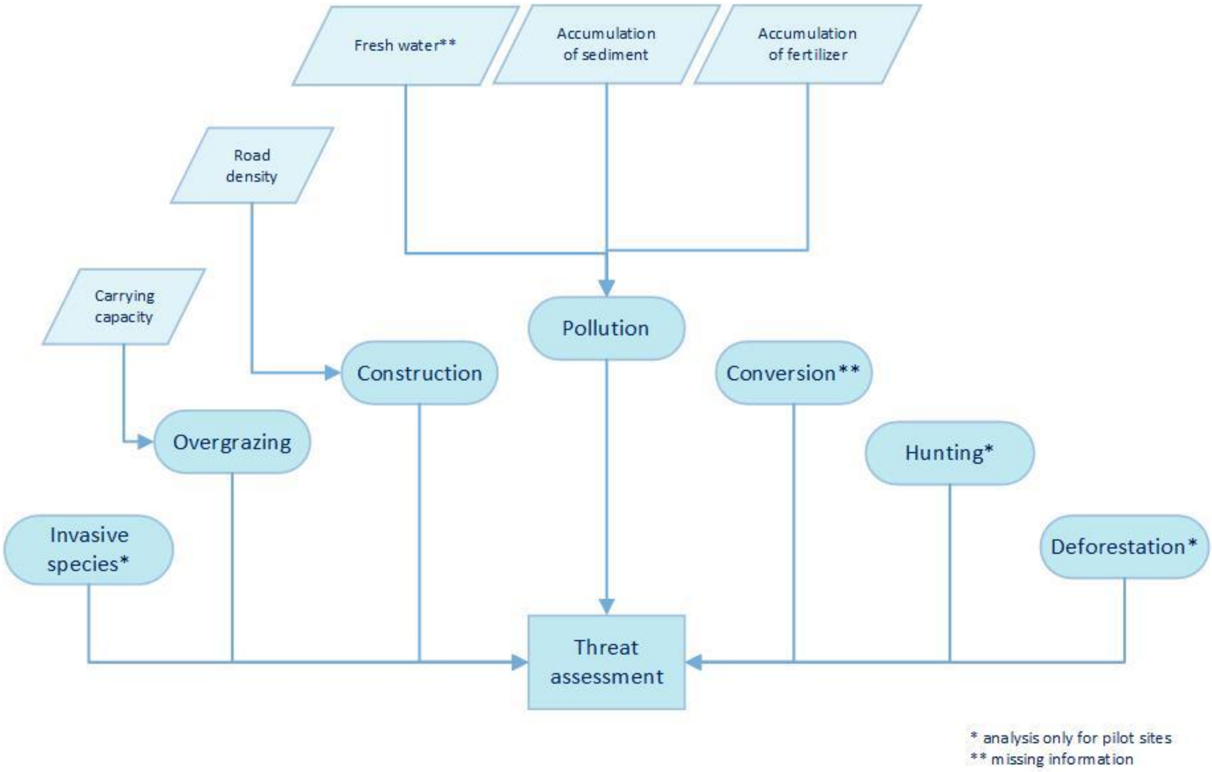
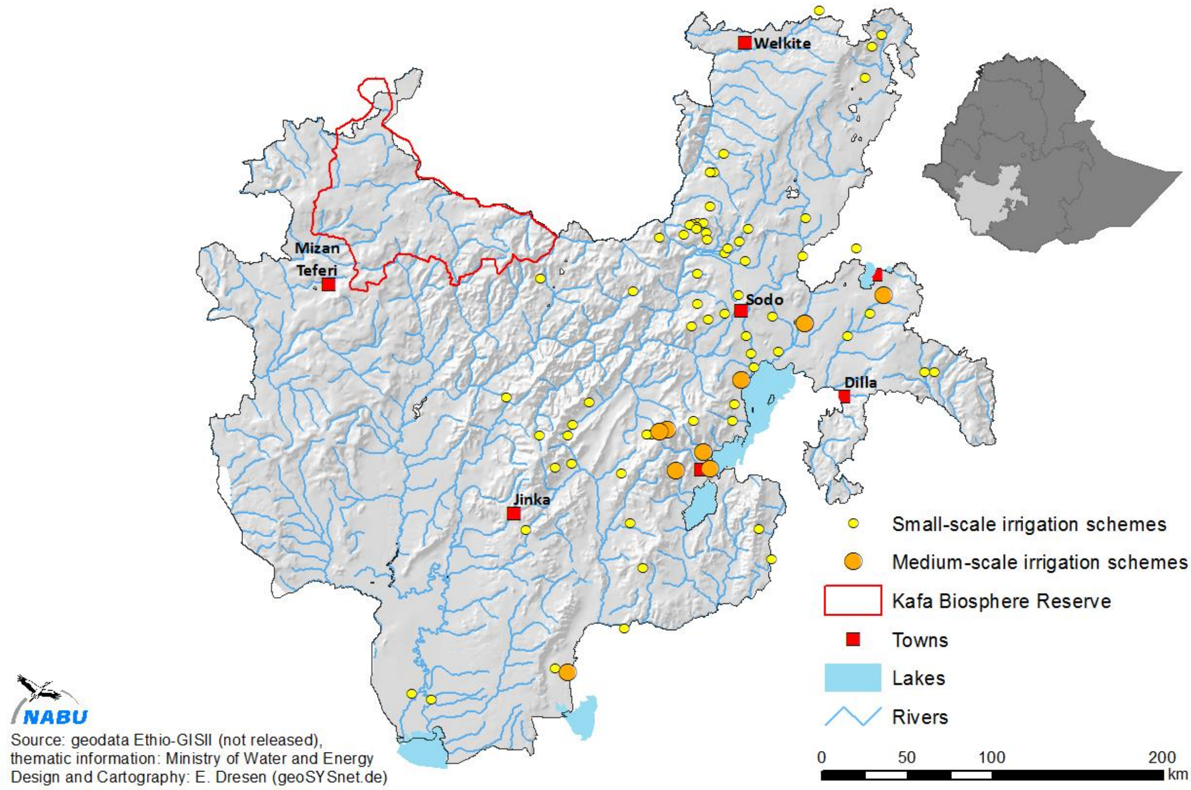


Figure 17: Flowchart of despriptors and processes to determine direct threats to wetlands within Kafa BR

From Tekalignes' general and systematic classification of threats for Sub-Saharan Africa wetlands, personal communication with local stakeholders, interviews and the evaluation of an online questionnaire highlighted the most direct threats to wetlands within Kafa BR. All answers of the questionnaire can be found in the Appendix (see REF) for results of the questionnaire see the interim report(Dresen 2014). The multi-criteria threat analysis model was adopted to the expert knowledge and weighted respectively.

Anyhow, for the Kafa Biosphere wetlands the mostly stressed direct threat is overgrazing and the conversion of wetland to other functions.

Comparisons with other Ethiopian wetlands and the factors influencing their ecological condition show that the Kafa region is not yet affected by agricultural draining. Anyhow, as the flow out of Baro Akabo and Omo Gibe river basin offer good conditions for large scale irrigation projects(Awulachew et al. 2007), this might create a conflict between conservation and development in the future. Possible environmental impacts of irrigation on natural resources affect the local water table, downstream water quality, soil quality, and directly all wetlands fed by the exploited water source(Ruffeis et al. 2006). On the other side, irrigation projects are a probate measure to fight famine(Awulachew et al. 2010) and support livelihoods of local communities (hand irrigation, small pumps). So far there are at least 107 existing irrigation schemes in the SNNPR, ranging from small-scale[15] to medium-scale[16] schemes. All of them are in the eastern areas of the Kafa BR (Map 4).



Map 4: Existing irrigation schemes in SNNP Regional State

In Figure 23 all direct threats to wetlands in general and for Kafa in specific are related to effects to the ecosystem directly or its providing function.

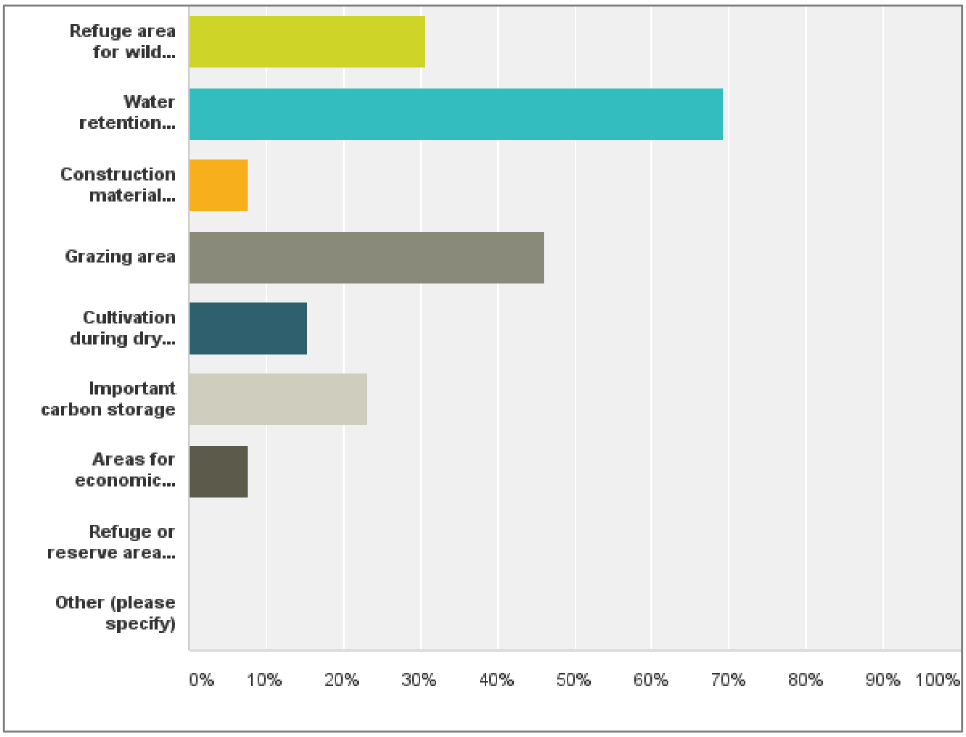
To be able, to cover all relevant threats, an online questionnaire was conducted seeking to determine the most relevant threats to the wetlands of Ethiopia, and in turn be able to calibrate the model for the threat assessment.

Some survey results are highlithed in the following, and the full questionnaire can be found in the appendix (Figure 49; page 187). The conducted Wetland Survey for Kafa Biosphere Reserve has been fully completed by 13 persons from the following institutions: Natural Resource and Environmental Office Addis Ababa, IWMI (International Water Management Institute), Bahir Dar University, GIZ Ethiopia, Ethiopian Wildlife & Natural History Society, Bonga Agricultural Research Center, NABU Ethiopia, Agricultural and Rural Office in Bonga, Ethiopian Mapping Agency, Ethio Wetlands and Natural Resources Association, Jimma University. The persons represent a good cross-section to international and national scientific research, governmental organizations and international development cooperation. This provides a good overview of different experiences and knowledge about Ethiopian wetlands, its resources, functions and threats.

[15] According to a classification of MoWR, small scale irrigation covers less than 200 ha
[16] According to a classification of MoWR, medium scale irrigation covers between 200 – 3,000 ha

An overview of the main results of the survey is given consecutively.

The first intrinsic question was related to the wetland functions and the experts view about the most important of these functions. Only two answers were allowed, so the results really contain the main functions. As shown below, 70% of the experts mentioned water retention as the main function of wetlands. The supply of water seems to be the most important ecosystem service, followed by “Grazing area” with more than 45%. This is noticeable, due to the fact that grazing is more a threat to the water retention than any other factor. Intensive grazing reduces the soil-moisture belt due to less soil cover and higher solar radiation and in addition to that, excrements of grazing activity worsen the water quality.

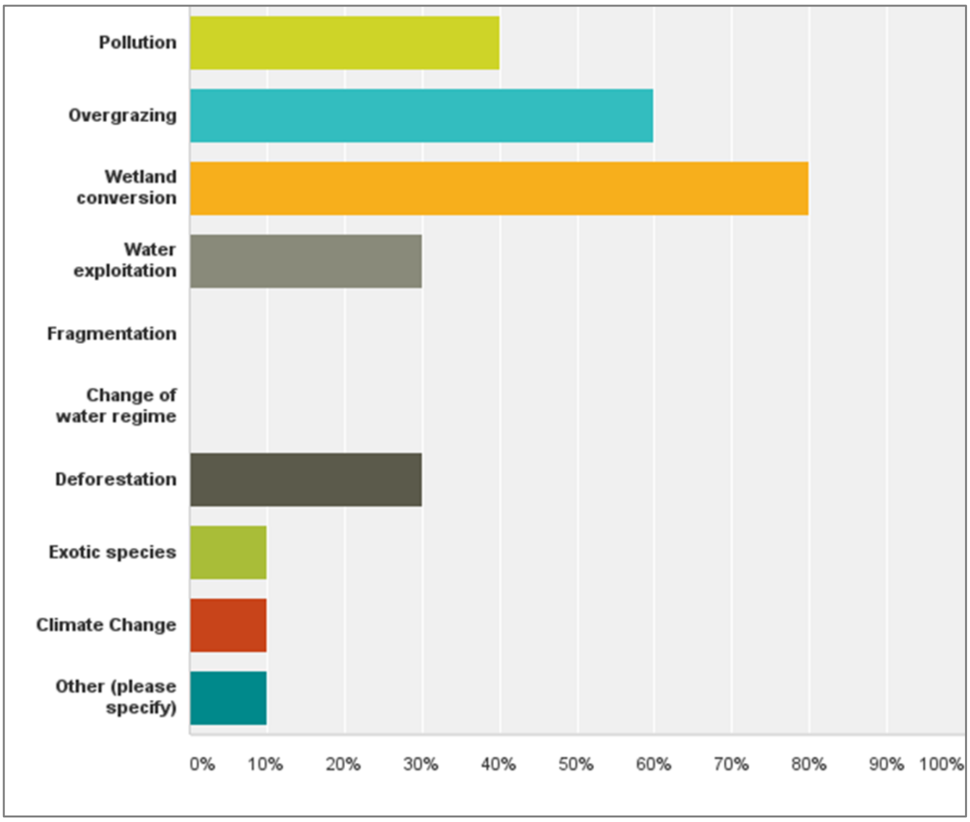


Refuge area for wild animals and rare flora		30,77%	4
Water retention function – supply of fresh water		69,23%	9
Construction material (reeds) for local people		7,69%	1
Grazing area		46,15%	6
Cultivation during dry season (to fight famine)		15,38%	2
Important carbon storage		23,08%	3
Areas for economic growth/ development projects (e.g. cash crops)		7,69%	1
Refuge or reserve areas for migrants and growing population		0,00%	0
Other (please specify)	Beantwortungen	0,00%	0

Figure 18: Answers to the question “From your opinion, what are the most important functions of wetlands? (just 2 answers)”

Thus, there is a contradiction of opinion between the two main functions of wetlands. This also clarifies, even wetland experts cannot decide between protection on the one hand (water retention, refuge area for wild animals [30%]) and economic use (grazing, cultivation during dry season [15%], construction material [8%], areas for economic development [8%]) on the other. This also implies the necessity to mediate between different positions, to find a way for using wetlands economically without undermining the protection function.

Concerning the threats for the wetlands, the experts named wetland conversion (80%), overgrazing (60%) and pollution (40%) as main threats to Ethiopian wetlands. This answer fits exactly to what was discussed earlier for water retention and grazing. Wetland conversion stands for economic use and conversion or destruction of wetlands, while overgrazing and pollution belong together and refer more to the water (retention) function of the wetlands.

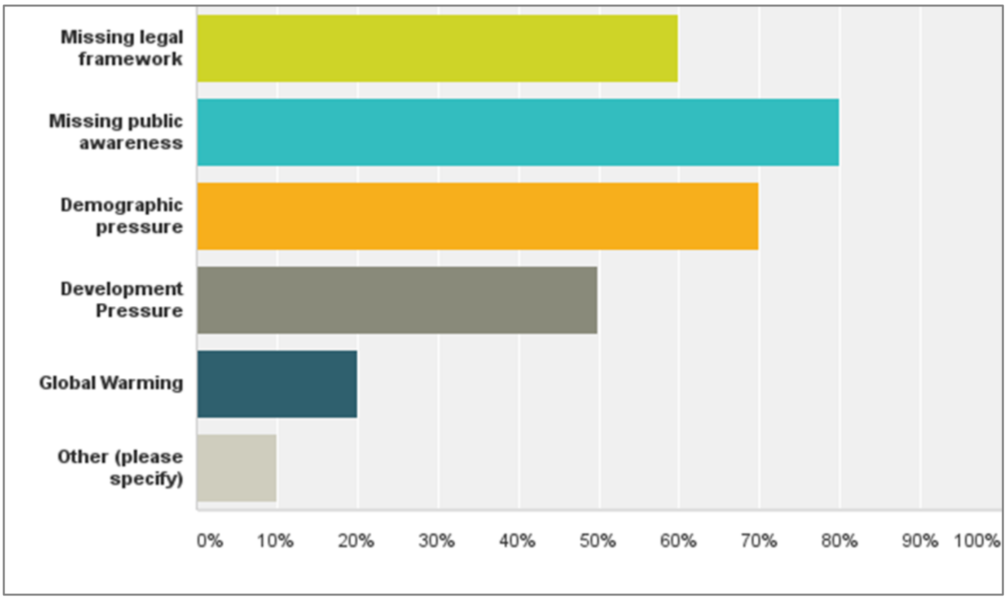


Pollution		40,00%	4
Overgrazing		60,00%	6
Wetland conversion		80,00%	8
Water exploitation		30,00%	3
Fragmentation		0,00%	0
Change of water regime		0,00%	0
Deforestation		30,00%	3
Exotic species		10,00%	1
Climate Change		10,00%	1
Other (please specify)	Beantwortungen	10,00%	1

Figure 19: Answers to the question “From your opinion, what are the most relevant threats to Ethiopian wetlands? (max. 3 answers)”

The underlying reasons are diverse. The experts nominated “Missing public awareness”, “Demographic pressure”, “Missing legal framework” and “Development pressure” as the – almost equal-ranking - main reasons.

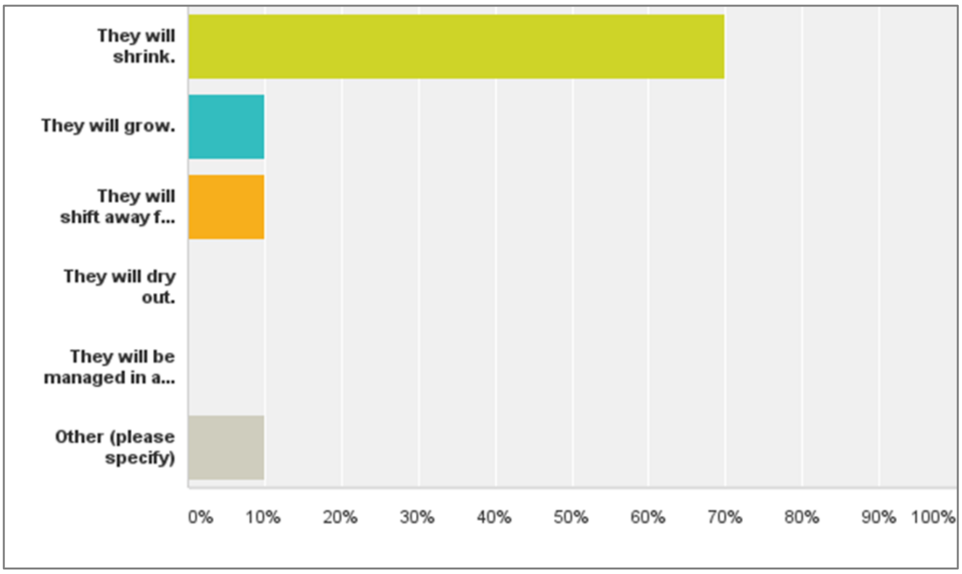
It is intrinsic that the provisioning of a legal framework could at the same time limit the other mentioned reasons. A legal framework certainly would create better public awareness concerning wetlands. The influence of demographic and development pressure would shrink due to formal restrictions and a better legal assistance for the protection of wetlands and its main functions.



Missing legal framework		60,00%	6
Missing public awareness		80,00%	8
Demographic pressure		70,00%	7
Development Pressure		50,00%	5
Global Warming		20,00%	2
Other (please specify)	Beantwortungen	10,00%	1

Figure 20: Answers to the question “What are the underlying reasons?”

However most of the experts are not very optimistic about the wetlands’ future, 70% of them assume that they will shrink. They don’t seem to believe in the execution of a legal framework or its effectiveness. It might also be that the threats are too diverse to be addressed by a legal framework.

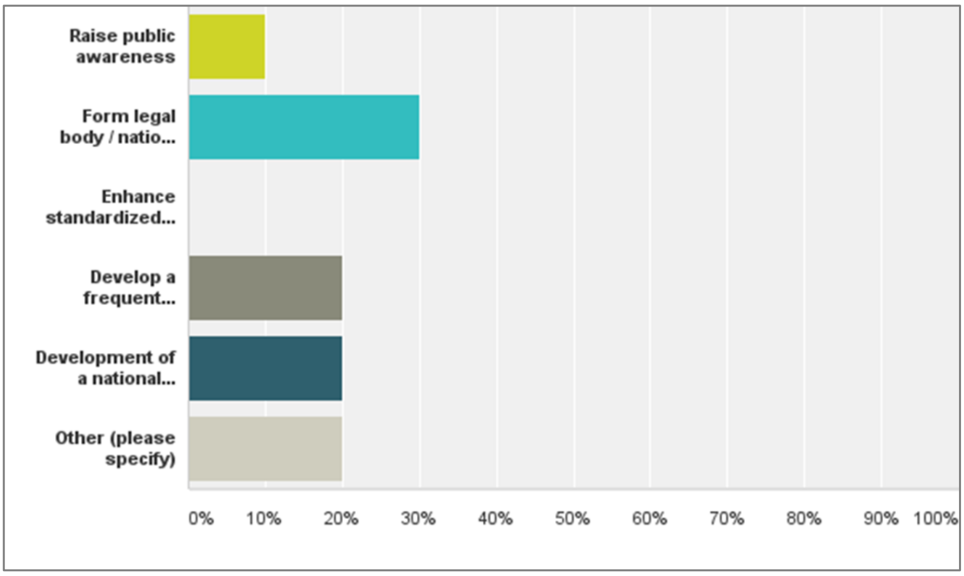


They will shrink.		70,00%	7
They will grow.		10,00%	1
They will shift away from the potentially natural vegetation.		10,00%	1
They will dry out.		0,00%	0
They will be managed in a sustainable way.		0,00%	0
Other (please specify)	Beantwortungen	10,00%	1

Figure 21: Answers to the question "What will be the future of Ethiopians' wetlands (your own opinion)"

It is not surprising that the experts do not agree about the action, which should be enforced to better protect Ethiopias' wetlands. Forming a legal body or national steering committee, developing a monitoring system, developing a national wetland database e.g. – the experts demonstrate the necessity to combine different actions.

In this context, a legal framework for wetlands could pave the way for any other possible action.



Raise public awareness		10,00%	1
Form legal body / national steering committee for Ethiopians wetlands		30,00%	3
Enhance standardized inventory of wetlands		0,00%	0
Develop a frequent monitoring system		20,00%	2
Development of a national wetland database		20,00%	2
Other (please specify)	Beantwortungen	20,00%	2

Figure 22: Answers to the question "What is the most important action to protect Ethiopias' wetlands?"

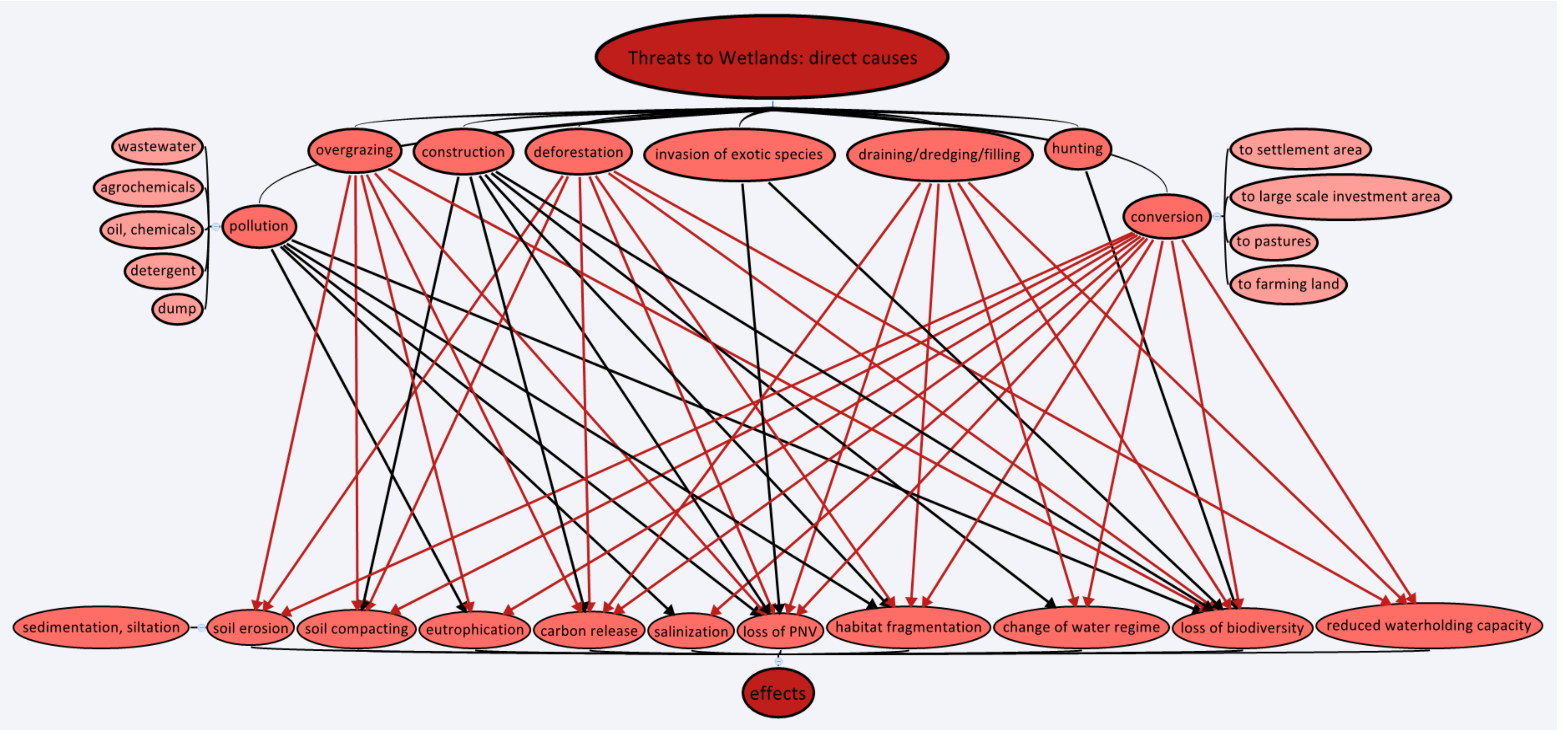


Figure 23: Threats to wetlands: causes & effects (by F. Mundt)

i. Overgrazing

One main ecosystem service mentioned in the questionnaires and highlighted at expert interviews of Kafa´s wetlands is the supply of fodder and grazing land for livestock. While in the early 20th century devasting epidemics kept the growth of livestock "in check"(P. N De leeuw and Tothilll J C 1990), today grazing areas are often intensively used – sometimes even without the possibility to regenerate and with a dominance of herbivores, which make a sustainable management impossible(Fao 1991). In this report this is referred as overgrazing.

Wetlands seem to be ideal for pastoralism, but the maximum possible stocking of livestock should be considered and taken into concern in further management decisions. Quantitative estimates are commonly based on the assumption that livestock require a daily dry matter intake equivalent to 2.5% to 3.0% of their bodyweight(P. N De leeuw and Tothilll J C 1990) described as the carrying or grazing capacity (CC). The numbers of CC for Ethiopia range between 1.5 – 2.5 TLU[17] per ha [TLU/ha].

To estimate the susceptibility of the wetlands according to overgrazing, the absolute numbers of livestock on Kebele level are converted to TLU[18] and related to alternative land for grazing. The flow chart represents the main steps.

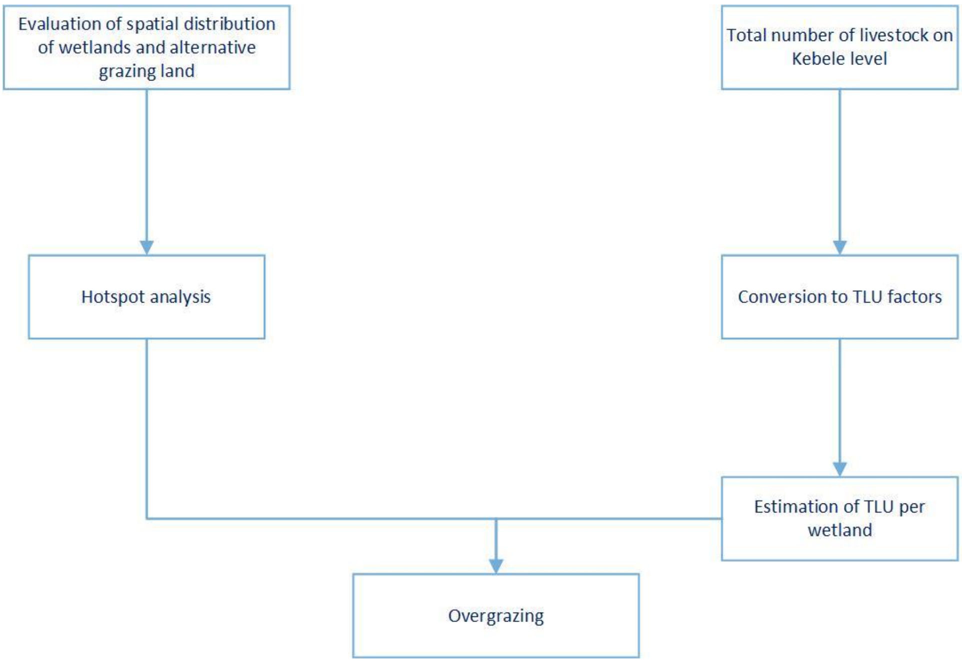


Figure 24: Flow Chart for estimating CC of livestock for wetlands

Baseline for the estimation of the grazing impact are the total number of livestock on Kebele level and the LULC, wetlands and other potential grazing areas (different kind of natural or secondary

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[17] TLU – Tropical Live Unit | in order to compare different species, they can be described by means of a common reference unit, equivalent to an animal of 250 kg (Fao 1991)

[18] Conversion factors can be found in the appendix (

Table 23: Weights and TLU conversion factors of livestock (after Jahnke 1982))

forests, meadows, bush and shrubland). To be able to estimate the proximity of potential grazing area to each other, thus estimating the possible alternatives to wetland grazing, a hot spot analysis was conducted (Results can be found in the appendix: Figure 51).

ii. Non-point surface pollution/ accumulation of fertilizer

Application of chemical fertilizer in Sub-Saharan Africa is still low, compared with other countries like Asia(Morris et al. 2007). But missing capacity for training has caused misuse and in some cases even led to the deterioration of soil fertility(Dittoh & Akuriba 2012). Anyhow, if the Growth Transformation Plan (GTP) is met, Ethiopia will double its consumption in a short-term(Shoals 2012). Consequently more material can leach as non-point source pollution, which is accumulated in sink systems.

Though empiric evidence in the Kafa BR is missing, the accumulation of fertilizer in rivers and wetlands is regarded as a direct threat. In general, accumulation of fertilizer can contaminate drinking water with high levels of nitrate(Atapattu & Kodituwakku 2009; Potter et al. 2010). Possible effects on the ecosystem itself due to enrichment of Nitrats and Phosphor can lead to an eutrophication and the negative effects are discussed in different literature (Potter et al. 2010; Billen 2009). Particularly, the improper application of fertilizer in Kafa Region leads to less efficiency, run off and leaching which cause an impact on the wetlands. The questionnaire(Dresen 2014) and expert interviews on local and regional level[19] show a consumption of 40% diammonium phosphate (DAP) and 60% urea fertilizers[20].

To estimate the possible fertilizer accumulation for all wetlands in the Kafa BR, the fertilizer application on Kebele Level were reassigned to pixel level and used as cost raster for calculating the flow accumulation. The workflow can be seen below (Figure 25).

[19] Ministry of Agriculture and Rural Development agents; GIZ; Ministry of Environment and Forests
[20] nitrogen fertilizer with an NPK (nitrogen-phosphorus-potassium) ratio of 46-0-0

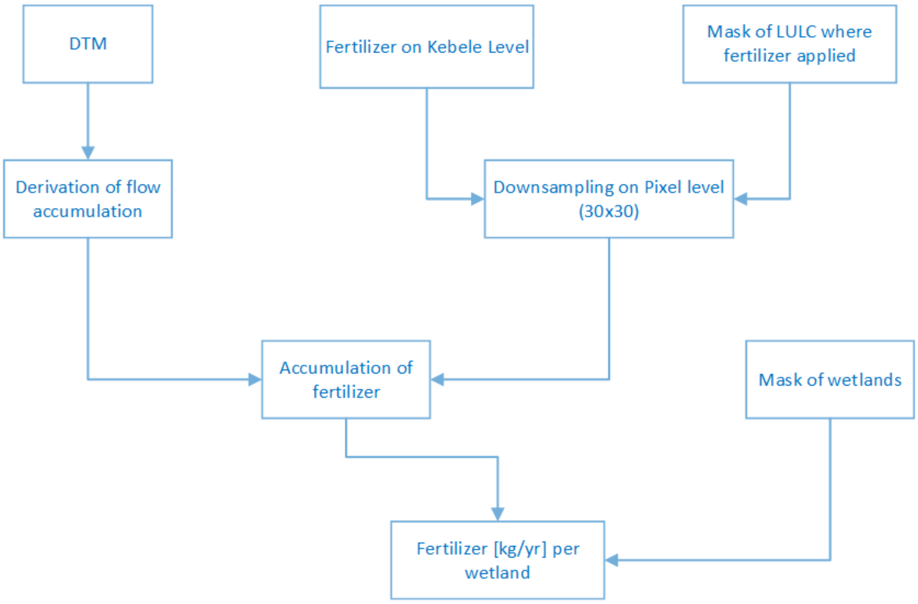

Figure 25: Flow chart for calculating the fertilizer accumulation per wetland

The model for calculating the fertilizer accumulation per wetland is based on a cost raster for fertilizer, integrated in the derivation of flow accumulation. In general, flow accumulation is a hydrological parameter, which can be used to model mass transportation and flow between land units. The flow accumulation matrix shows cell values which are assigned a value equal to the number of cells that flow to it. Water flows to the lowest area accumulatively, thus the lowest area will collect the water flow from all cells in the area(Gold et al. 2005). Therefore, wetlands are prone to accumulatively collect all transported "pollutants" from the catchment. The integrated cost raster represents the fertilizer [kg/yr] calculated per pixel (30x30 m). Though the cost raster represents only LULC where fertilizer application is assumed (agriculture, tea plantation, homegarden), only the surface flow is determined which implicates the limitation of the model. The amount of fertilizer not penetrating the soil and absorbed by plants is difficult to estimate. It depends on the time of application (dry- or rain season), on the product used and on vegetation and soil parameters. Though the model gives absolute values for fertilizer accumulation, it is only valid for the comparison between the wetlands because it predicts the maximal fertilizer accumulation, assuming that no amount is absorbed by plant uptake or soil retention.

The interim result for estimating the non-point surface pollution indicates that wetlands mainly fed by rivers are very likely to accumulate huge amounts of fertilizer. If the wetlands main water source is from precipitation or groundwater, the effect of fertilizer input is less strong. Though is seems to be plausible, this result is only a model outcome never referenced on the ground. Consequently, before drawing out management strategies of that, water analysis in wetlands with predicted high accumulation and low accumulation is strongly recommended. Unlike presumed, there is no statistical significant relation between the amount of fertilizer accumulated and the altitudinal position of the wetland (R^2=0.002).

Results are shown in Map26: Application of Fertilizer in Kafa BR.

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iii. Construction

The trade-off between ecological protection and development is often highlighted in the context of the Amazon rain forest and road construction. In general, road construction and good infrastructure can lead to accessibility to markets, which in turn effects the exploitation of ecosystem services. Additionally, the road construction and existing roads give access to remote areas for initial exploitation. In this analysis, solely road density is selected as proxy for construction and development. Though there are no references proving a statistical significant correlation between the degradation of wetlands and road density, we anticipate a strong dependency. As this point was often highlighted as major threat in various interviews, it is integrated into the spatial threat assessment. Road density of different road types (track, dry weather, gravel, all weather roads) was assessed and weighted, since we assume a different potential for development. The weighted distance was related to the wetlands in Kafa BR and finally expressed as an index for accessibility. Limitation of the construction model is the poor baseline data for roads especially in remote areas. This may lead to an underestimation of areas affected by construction.

Table 8: Threat assessment rating with impact on the ecological condition, on the ecosystem service and on biophysical properties

Threat scale	Impact on ecological condition	Impact on ecosystem services	Impact on biophysical properties
5 - Very low	No significant change in ecological condition	No adverse impacts for benefited communities, no impacts for downstream population.	No change expected
4 - Low	Some changes in the ecological condition – a decline in “naturalness” is possible.	Minor adverse impacts for local communities, decline of sensitive species possible (medical plants), no impact for downstream communities	No change expected
3 - Moderate	Measurable change in the ecological condition – noticeable decline in “naturalness” – is possible and the prospect of the decline or extirpation of some species cannot be discounted.	Bidirectional impacts possible, selective browsing at a specific time in the year changes plant communities, other plants might benefit from nutrient input, impacts on downstream communities are possible. A frequent monitoring of water quality is recommended.	Minor changes in topsoil condition on a long-term possible
2 - High	Significant change in ecological condition – a noticeable decline in “naturalness”, main impact on flora through steady grazing, impact of invasive alien species possible, pollution of water by accumulated fertilizer and other	Impact on services from fauna and flora is significant; service scarcity is temporarily possible depending on season. Adverse impacts for communities living downstream are possible	Change of hydrodynamic characteristics possible, on fluvisols compaction possible with the result of diminished water holding capacity, very low C_{org}

	transported substances likely		
1 - Very high	Highly significant change in the ecological condition with adherent loss of typical wetland species.	Most ecosystem services are diminished or disappeared. Severe impacts for downstream communities.	Altered hydrological regime, loss of water retention capacity.

All descriptors for the threat assessment are combined in a spatial model and scored according the weighted threat. The full model can be found in the appendix (Figure 53).

e. Classification of wetland importance

The „importance“ of a wetland as a functioning ecosystem is difficult to measure, which ideally is a multidisciplinary approach. Generally, it can be considered from different scales, as the availably of clean water has serious impacts on landscape level while carbon sequestration is more of global concern. On the global level concern, information about the importance of wetlands for birds and threatened species among all existing wetlands in Kafa BR (the ones easy to reach are already nationally recognized as important bird area) are relevant. Species of concern, like threatened or endemic species typically known as wetland vegetation, should be monitored and reported. So far, there are no typical wetland species known, having a status of threatened or endemic (chapter 4.a). On a landscape scale, the particular importance of a wetland should be assessed by determining if there is a specific wetland service, which is highly important and non-substitutable by other sources. This might be a wetland within a drought savannah like landscape matrix, or in general the local water supply.

Our analysis concerning the wetland “importance” is, due to a lack of information only rudimentary but could be enhanced when further information (especially on global scale) is available.

All wetlands are considered to be hydrologically important, and the three descriptors below seek to determine whether a wetland is particularly important from the point of view of having identifiable downstream beneficiaries, and have a major contribution to the livelihoods of many communities with limited alternative livelihood option. We try to estimate the impact on downstream communities in terms of fresh water; where no alternatives exist and locally many people are affected by a diminished service. Furthermore, the contribution to social welfare is estimated with a proxy of distance to major towns. It might be reasonably assumed, that the contribution to social welfare currently provided by the wetland decreases with increasing distance to the next town. And lastly, we seek to determine the “importance” of the wetland by analysing the possible alternatives by identifying statistically significant hot spots and cold spots of present wetlands.

Although enhancement of sustained streamflow for downstream beneficiaries is not considered specifically, water users deriving benefit from water purification are also likely to derive benefit from sustained streamflow. Ability of a wetland to influence water quality and attenuate floods decreases with increasing distance downstream of the wetland outlet, and from an assessment point of view it becomes increasingly impractical to assess downstream influence as downstream distance increases. Hence, a cut-off of 12 km is used.

It should be emphasised, however, that there are several interacting factors determining the wetland's contribution to social welfare, including the species composition, the hydrologic regime and the size of the wetland. Consequently, a field visit with a participatory rural assessment should be conducted before taking ad-hoc decisions.

The spatial model can be found in the appendix (Figure 54).

Table 9: Assessment of a wetland's contribution to social welfare

Score	Description
5 - Major contribution	For almost all local communities, the wetland constitutes as the most important contribution to their livelihoods through provision of water (domestic and livestock), cattle grazing, labour, construction material, and medicinal plants, it is likely that the wetland makes a very significant contribution to communities downstream; no water alternatives are available
4 - Significant contribution	For adjacent local communities the wetland provides a significant contribution to their livelihoods, it is likely that the wetland makes a significant contribution to the welfare of some people living downstream
3 - Moderate contribution	For many local communities, the wetland provides an important, but not necessarily vital, contribution to their livelihoods. In many cases alternatives could be found. It could be, that the wetland provides some benefits to some people downstream.
2 - Small contribution	For some local communities, the wetland provides an important, but not necessarily vital, contribution to their livelihoods. In many cases alternatives could be found.
1 - No significant contribution	The wetland provides a benefit only for some people, but alternatives could be found.

f. Recommendations for conservation

On the regional level, wetlands are classified according to the ecological condition of the wetland based on to proxies – the pressure of exploitation on the ecosystem services and the availability of alternatives in the vicinity; benefits on a landscape scale while seek to determine the benefit for downstream population and spatial distance to towns in relation to alternatives; and finally assessing the main direct threats (overgrazing, construction, and pollution) to formulate a recommendation for conservation of wetlands within Kafa BR. As not all factors, like presented in the "Conceptual model for the conservation recommendation in Kafa BR" (Figure 2) could be included and the importance of missing factors is unknown, the recommendations should be interpreted with great caution and should be used as baseline for further on site investigations.

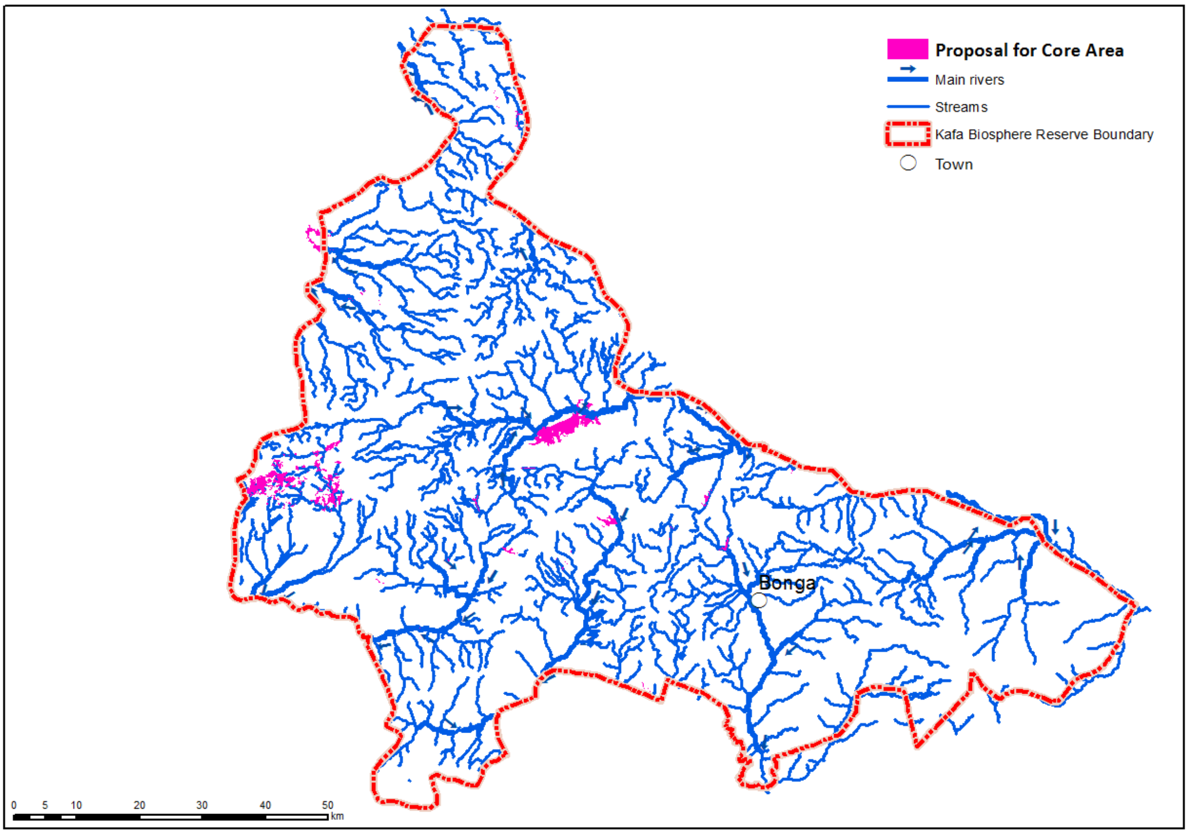
The results for all three components are cartographically presented and can be found as preview in the appendix, and with more detail on the included DVD.

The focus is to determine different management zones according to the concept named in the Terms of Reference (Contract number: 03/2014_No.1 | Project: Biodiversity under Climate Change: Community Based Conservation, Management and Development Concepts of the Wild Coffee Forests | page 3), with:

a) Area to be strictly protected as core zone due to outstanding natural value as unspoilt pristine reference area
b) Area to be restored and renaturated in order to regain a most natural state
c) Area to be transferred to sustainable community management and accounted for buffer zone

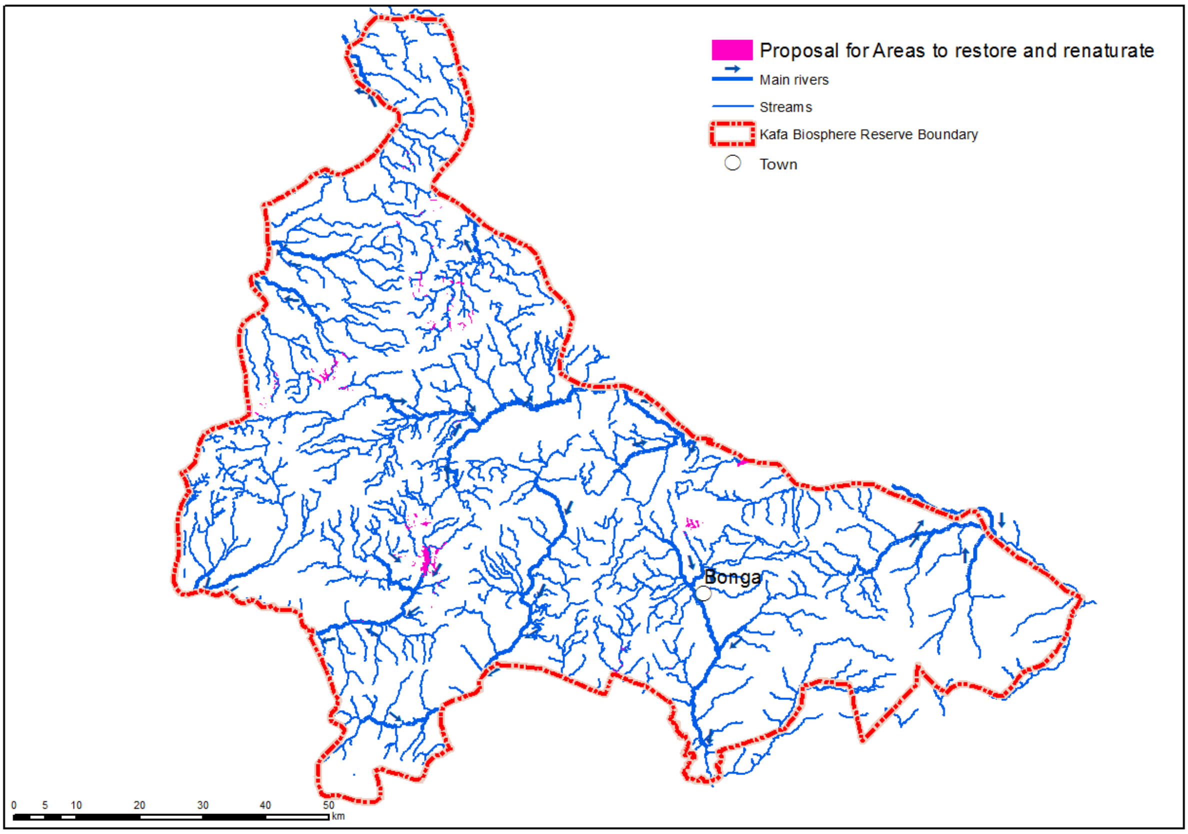
In the following, all differernt “management” zones are depicted and spatialized. This should not directly lead to an implementation, rather it should follow an on site survey.

a) Core zones are very delicate to draw on a sketch, due to the comprehensive restrictions for local communities. If not developed by a participatory process, in most cases the local communities would insist on their use rights on communal land and the natural resources inherent and scorning the „prohibition of use” imposed. Having ascertained the existing ecological condition of the wetland and its contribution to social welfare it is advised to couple those areas with a high “naturalness” with little contribution to social welfare. With this, conflicts between ecological protection and development are overcome. For Kafa, this would result in an area of approximately 6,350 ha core area. The spatial distribution shows, that especially in the western part of the BR, vast connected areas can be found, fulfilling the criteria. According to the topographic maps, this wetland consists of bamboo thickets and wetland vegetation above 1 m and a very shallow water table (0.5 m depth). It includes the Gucho swamp, Shoshi swamp, Difin swamp and the Ichifa swamp. At the latter, serious deforestation in the adjacent high forest could be detected via satellite image interpretation. The other connected area is the southern floodplain of Gojeb river. This coincides with the findings of the detailed pilot site assessment of Gojeb river and is described in chapter 5.b.v (page 118).



Map 5: Proposal for core areas

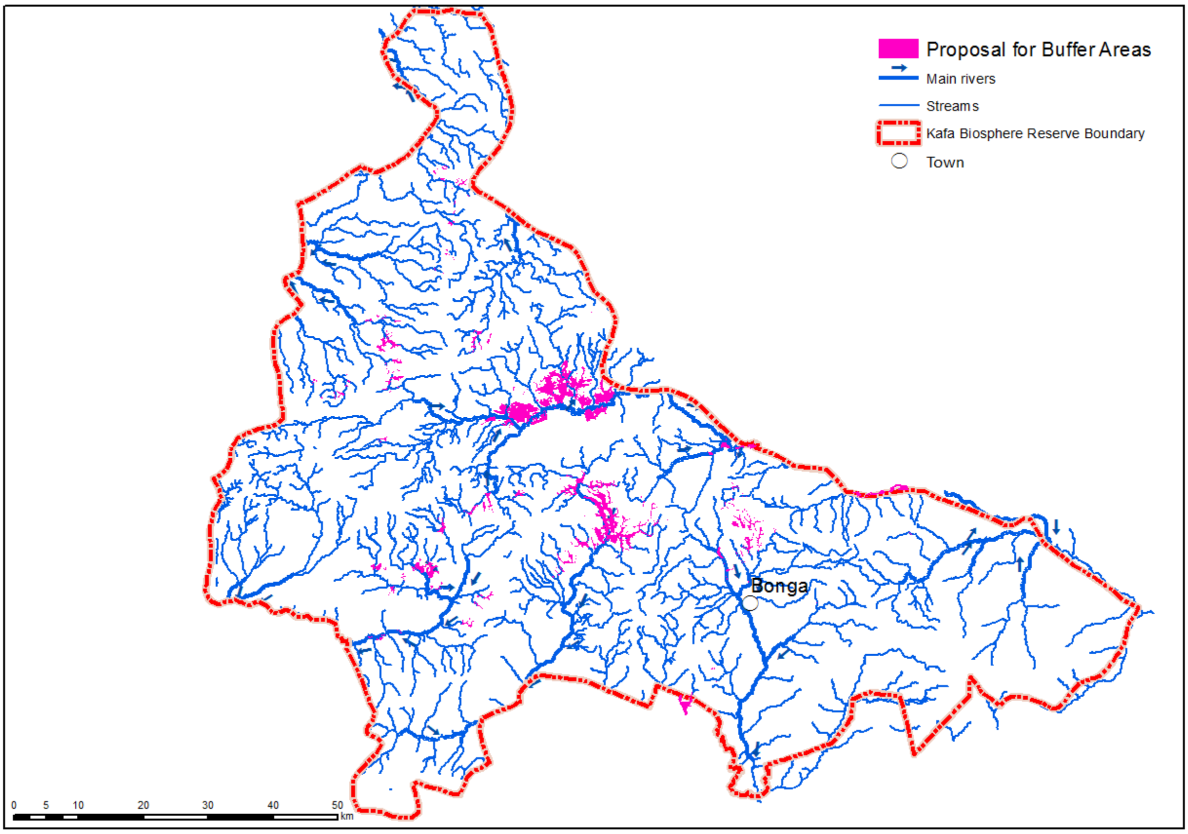
b) Areas to be restored and renaturated requires a lot of resources and efforts should be sustainable. Those areas can be found elsewhere in the Kafa BR, regarding the threat analysis. To fit into a long-term sustainable concept, selected areas should not have a major contribution to the social welfare because most wetlands are extensively modifies and the ecosystem is significantly altered from its perceived “natural” state. Consequently, for proposing sites to restore we coupled those wetlands having small or no significant contribution to social welfare with sites exposed to very high to high threats. As the threat assessment includes NPS-pollution, overgrazing, and development it is important to further investigate the selected sites and address the most dominant cause. The best and sustainable results of renaturation are to develop strategies eliminating the causes. For Kafa BR, sites with a spatial extent of 2,000 ha consisting of many small patches with a mean size of 4 ha. The most connected site for renaturation is located east of Bita Genit town, namely parts of Beko swamp, A-Acha swamp and Mera Kuni swamo which is framed by intense agriculture. This might cause some conflicts and should be well discussed with experts and local communities. Another major part lies in Alemgono wetland which coincides with the management proposal of the pilot site. Details are described in chapter 5.a.v.2 (page 93).



Map 6: Porposal for areas to restore and renaturate in Kafa BR

c) Area to be transferred to sustainable community management and accounted for buffer zone, should ideally provide physical benefits to as many people in local community and downstream populations but not jeopardize the sustainable use of wetland resources. Futhermore, in different sites a proper resource management is urgently needed and could hamper the expected (further) degradation of the wetland followed by resource depletion.

For this assessment, we suggest those areas with a moderate up to a major contribution (which might be challenging to convert in a sustainable management) to social welfare and exposed to moderate up to very high threats. For Kafa BR the spatial extent proposed as buffer zone is 12,370 ha of mainly vast, connected areas. The biggest share covers the northern floodplain of Gojeb wetland, which coincides with the detailed management recommendations of the pilot site (chapter 5.b.v.2; page 127).



Map 7: Proposed Buffer Areas for Kafa BR

PART 4 Pilot Sites

5. Pilot Sites in Kafa Biosphere Reserve

The pilot sites were selected due to NABU HQ and NABU Bonga advice. The in depth analysis for the selected sites includes testing against criteria for the delineation of the wetland boundary. A literature review was conducted to reveal the most important wetland indicators for delineation and mapping of wetlands (Schmied 2008; Mark M Brinson 1993; Rodhe & Seibert 1999; Tiner 2000; Smith et al. 1999; Lewis 1995). As a wide range of classification exists, we focused on criteria which are able to show the actual state of the pilot sites and give management recommendations. All criteria were compared with existing data, and the conduction of surveys for all missing information relating to resource intensity and data frame was evaluated. The most important criteria could be included in the pilot site assessment, whereas some criteria should be studied more intensely in the future to be able to concretise and extrapolate classification results. Information about geology with soil types and water table seasonality (hydrology) could only be superficially included.

Table 10: Criteria for pilot site assessment

Criteria	**Indicators**	**Assessment method**
Hydrology/ Topography	Relief/ Slope gradient; Landscape position and landform	DTM
	Height; Amplitude of water level	DTM; Field visit; key informant; IDI
	Origin of water	DTM
	Wetness index	DTM
Soil	pH value	Soil analysis
	Containing organic matter	Soil analysis
	Soil colour	Soil analysis
Vegetation	Dominant wetness vegetation	Flora assessment
	Peat accumulation	Test drilling in all pilot sites
	Dominant crop type and growing season according to seasonal cycle (e.g. if maize is grown in dry season)	Field visit; key informant; IDI
Naturalness	Signs of grazing, agriculture, settlements, accessibility	Field visit, spatialization, spatial modelling
Threat assessment	Vegetation (overgrazing)	questionnaire (online, in-depth, key informant), field visit

The general work flow for the pilot site assessment looks as follows:

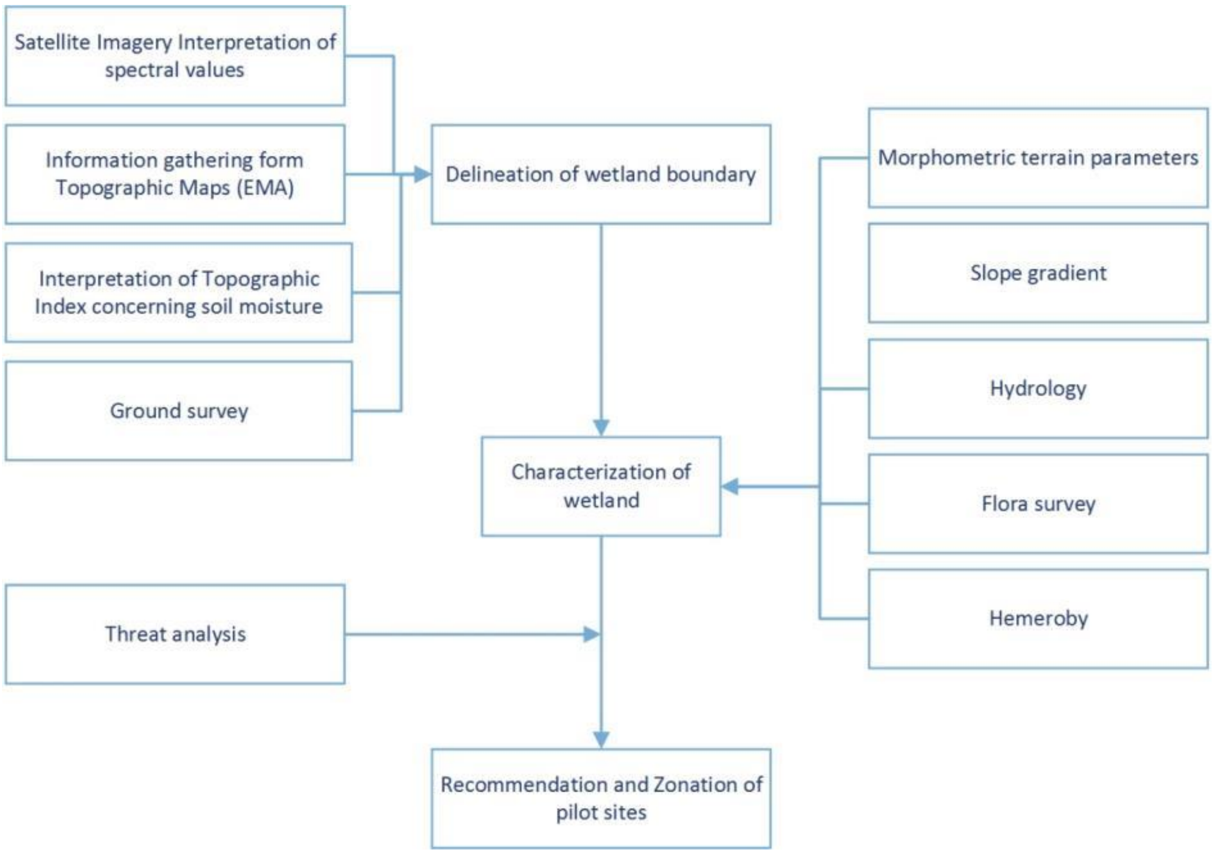


Figure 26: Work flow of pilot site assessment

An initial step was the identification and delineation of the wetlands in the pilot sites. Therefore different sources and techniques were applied. Based on 2.5 m resolution satellite imagery (SPOT5 2011), digital numbers (reflectance, intensity) were classified according to knowledge from past field visits (supervised classification). An object based classification removed all artificial non-wetland objects from the classification (out-masking). The identification result was improved by the attributisation of topographic maps (EMA) and delineation results could be enhanced by incorporating the topographic wetness index.

To characterize and classify the pilot wetlands, different parameters were evaluated. Morphometric terrain parameters are important to generally compare different stream networks and landscapes which are dominated by hydrologic dynamic. Slope gradient can give valuable information of the position in the landscape, furthermore it determines flow direction and stream velocity. Hydrologic characterization is also an important descriptor, as directional flow can determine if the wetland is a source, sink, or pass-through system(Tiner 2000). The latter named abiotic components are found to be correlated with wetland functions and are combined in a hydrogeomorphic classification system (HGM) after Brinson (1993). The classification is mainly based on three geomorphologic components(Mark M Brinson 1993), which are:

- Geomorphic setting, which describe the position of the wetland in the landscape concerning topography, geologic origin, and position relative to surface bodies. This is important as it determines how water enters the wetland and how much water the wetland is capable of storing

- Water source, which describes the origin of the principal water that enters the wetland (precipitation, groundwater, lateral-flow-surface and near-surface-flow) --> limitation on this, no knowledge of chemistry (instead flow path) and
- Hydrodynamic, which refers to the direction of the surface and near-surface water that enters the wetlands and associated energy level of those flows (e.g. the capacity of that water to transport sediments, flush hypersaline water from sediments, and transport nutrients to root surfaces)

Most of the geomorphologic parameters could be determined from the DTM and field visits, but some information could only be assumed or could not be included. This includes information of geologic origin and lithology, knowledge about water chemistry and soil types, and a quantitative analysis of hydrological components, like measurements of water table.

As the flora is the focal point for natural resource conservation issues, and as it is a product of hydrologic and geomorphologic factors, it is the primary criterion for characterizing the pilot wetlands. Due to a strong influence of human activity in the pilot sites, it is important to give an impression of the naturalness of the pilot site. The hemeroby is giving the status and stability of an ecosystem as it is today. According to the level of natural regeneration, it is possible to distinguish between the regeneration levels of “natural vegetation/ without human intervention” (level 5), “close -to-nature/ minor human intervention”, “influenced by human interventions”, “dominated by human interventions”, and “completely degraded” (level 1).

All abiotic and biotic factors give a full picture of the pilot sites. Finally, the formulation of existing and potential threats helps to develop conservation recommendations. The threat assessment is mainly based on field survey observations, supported by a geospatial analysis.

Finally, information is spatialized, evaluated and cartographically mapped as zonation.

Field work has taken place from 2nd of December 2014 to 12th of December 2014. Within the given timeframe all three pilot wetlands have been visited and the vegetation and simple soil parameters have been investigated.

In preparation of the field work, an initial polygon map was drafted from interpretation of high-spatial-resolution satellite imagery. Information for clustering and classifying the polygons were derived from hydrologic modelling (to distinguish between a moisture gradient), and spectral and object based image interpretation.

The field team used this information as a starting point and verified or modified formation boundaries, split or merged formation polygons and characterised each alliance type with quantitative data. Due to the size of the pilot sites and the partly impassable terrain, the field team decided to investigate pre-selected exemplary sample plots that covered all polygon classes on the draft map. The pre-selected plot locations have taken accessibility in the given time frame into account. Easy accessible replicate polygons along the way were also visited, to verify the affiliation to the considered formation. During 10 days of field work, 34 vegetation plots of approx. 5 m^2 within

4 wetlands of the Kafa Biosphere Reserve had been established and investigated: 8 in Chidi Wetland, 14 in Alemgono Wetland, 9 in Gojeb Wetland, and 1 in Shorori Wetland. A further 2 sites in the surrounding of Gojeb Wetland, which were previously misleadingly classified as wetlands, have been visited and rapidly described, but later excluded from the vegetation classification. Plot location within the wetlands of the chosen Pilot Sites can be seen in Map 8, Map 9, and Map 10.

Within the established plots the total vegetation height and cover was determined. All occurring plant species were determined after Hedberg and Edwards (1989-2009) and the respective coverage of the different species was estimated in percent. All species which could not be identified on species level in the field were labelled with working names.

In addition, the following site characteristics were recorded if possible: land use, soil type, current water table height, water table height during the rainy season, pH value, conservation status, threats, hemeroby.

In the field the pH-value of the soils was determined with an indicator strip (Macherey Nagel 0 - 7)

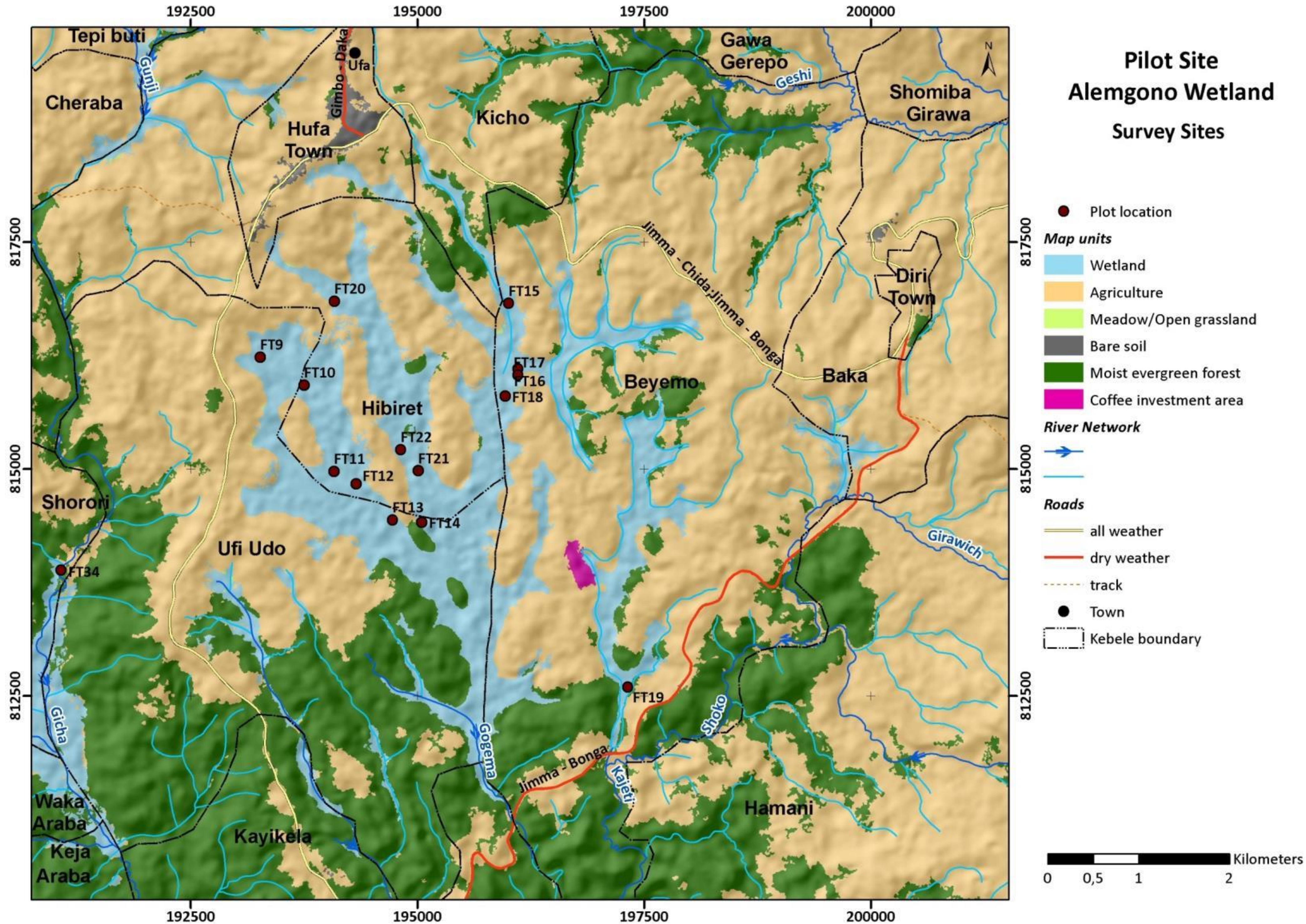
The field team sketched boundary modifications and dissected or merged polygon classes on hard-copy prints (A1 format, scale 1:10.000 / 1:18.000, provided with a UTM grid), which were taken to the field.

To describe the vegetation of the investigated wetlands a discrete classification system had to be developed due to the absence of established high resolution wetland classification in Sub-Saharan Africa.

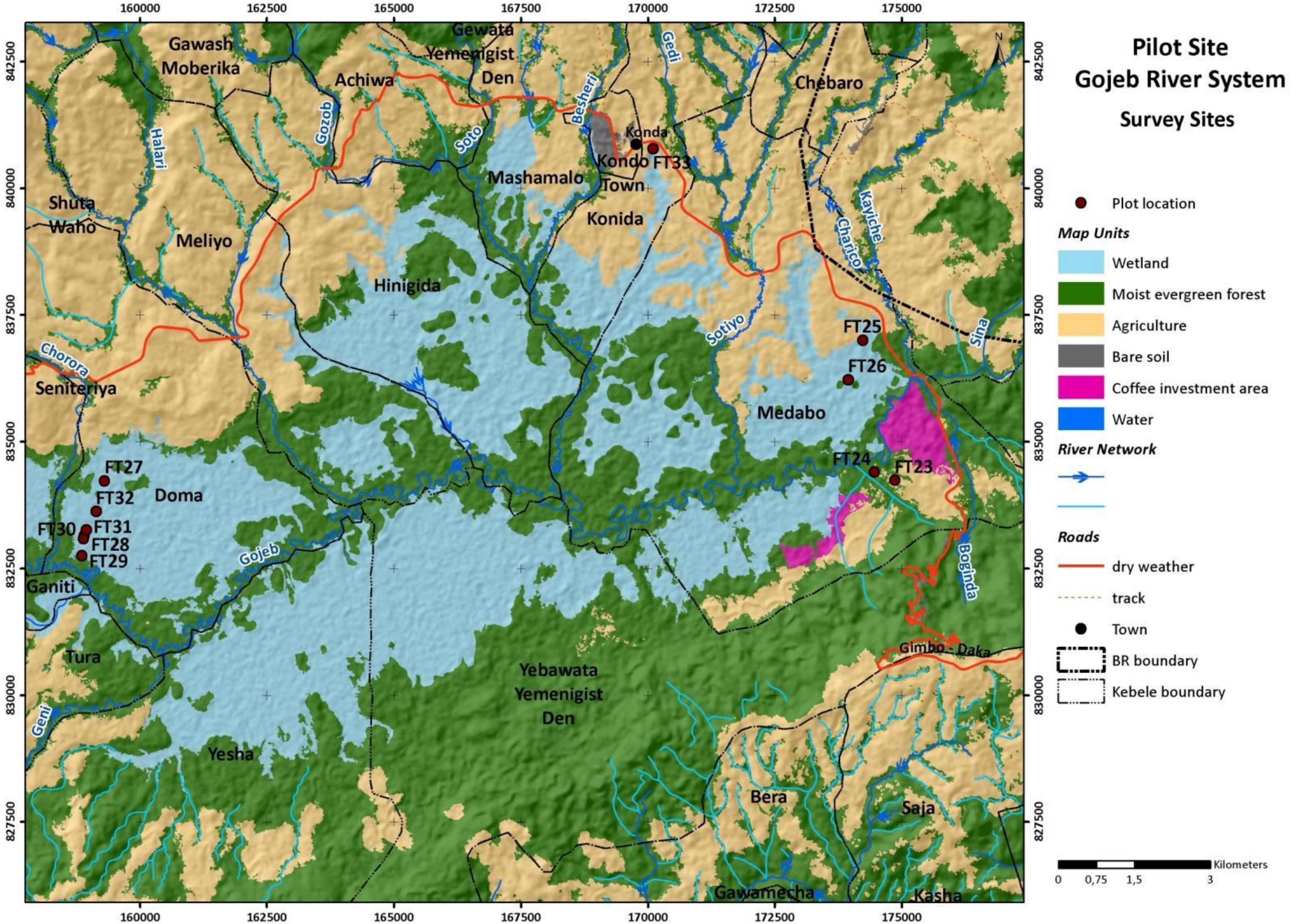
The data of the vegetation records were arranged in a table. Vegetation units were formed based on species composition. Plant species often occurring together and presumably reflecting the same environmental conditions are arranged into species groups. Different combination of such groups and frequently occurring species are summarized into the resulting vegetation unit. From different combinations of dominant and attending plant species, inferences towards different site conditions as the water regime, soil conditions, trophy status, land use and hemeroby can be derived (Table 28).

For naming the vegetation units we adapted the standardized UNESCO-TNC system (Vegetation Subcommittee (FGDC) 1996), in which the associations are described by the scientific name of the dominating species and the common name of the association structure. We enlarged the scientific name of one typical attending species to more precisely differentiate the investigated vegetation characteristics and connected site conditions.

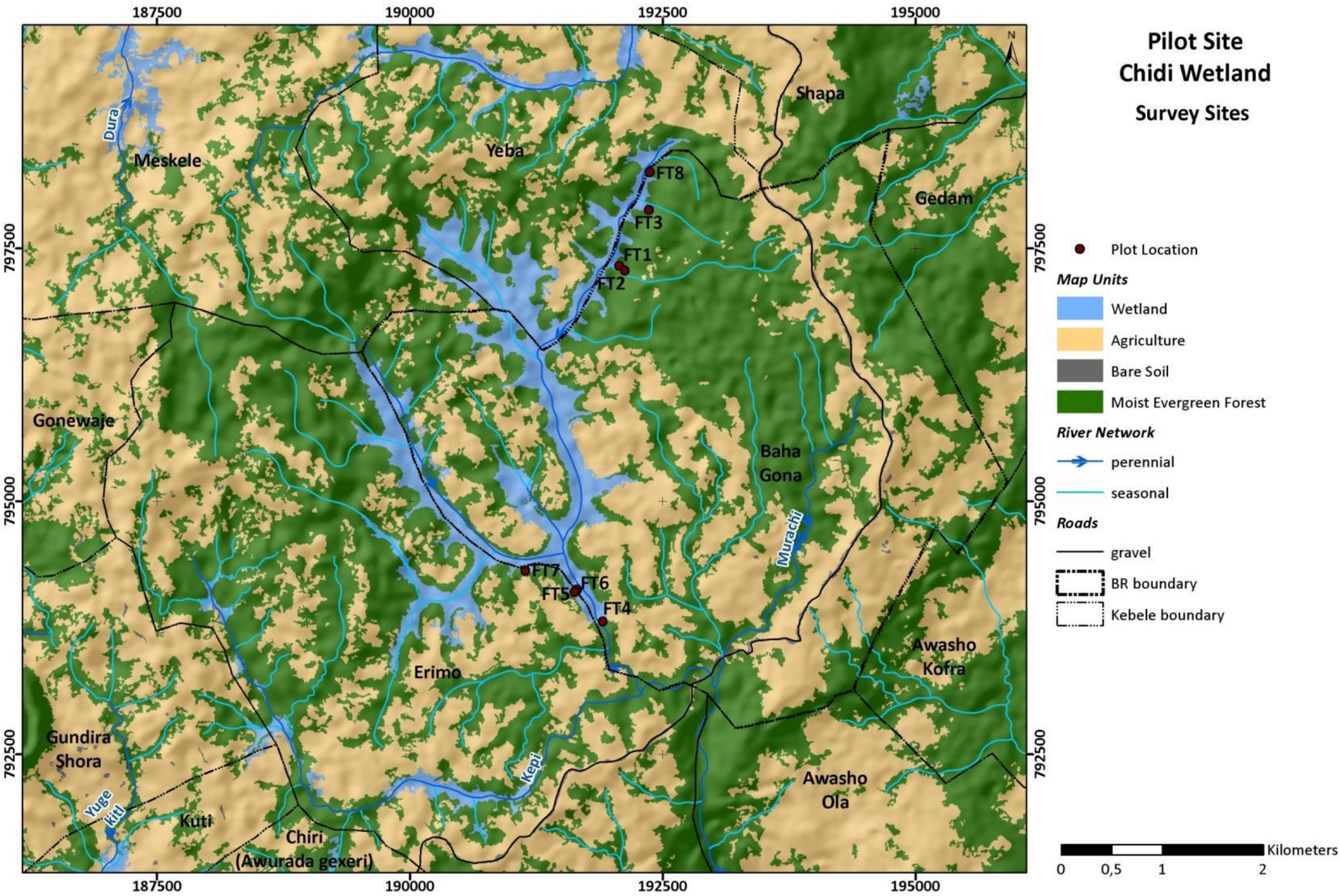
The resulting vegetation units were used as mapping units to visualise the vegetation characteristics of the wetlands in maps using GIS. As vegetation units are not discrete but boundaries are often diffuse, the polygon boundaries of vegetation units in all maps should be interpreted as fuzzy. Final map classes had been established according to the vegetation classification 8.



Map 8: Survey Sites, Alemgono Wetland



Map 9: Survey Sites, Gojeb River System



Map 10: Survey Sites, Chidi Wetland

The wetlands are dominated by species of Cyperaceae, ferns and Poaceae which are adapted to wet soil conditions and annual or seasonal high water levels or inundations. This characteristic vegetation composition is typical for wetlands and displays a reliable indicator of peat lands and other wetlands in the Kafa zone.

The very frequent Cyperus latifolius, which occurs in every investigated wetland in dominate stands can be regarded as indicator species. According to the IUCN Red List (IUCN 2014) neither threatened nor endemic plant species were found. Nevertheless in each of the wetlands we find characteristic wetland vegetation formations that result from the relief of the wetland and the surrounding landscape, which further influences the abiotic site conditions like hydrology and nutrient supply. These environmental conditions are mirrored in a typical plant species composition. Furthermore human activities like grazing, cutting and cultivation have a huge influence on the appearance of the wetlands and their habitat function.

Vegetation units

The vegetation of the three pilot sites was divided into nine units of typical species composition and indicating specific environmental conditions. From the nine vegetation units eight mapping units have been derived to visualise the spatial distribution of the vegetation. Two units of pastures dominated by Cyperus latifolius have been merged, because it was not possible to distinguish the units on the satellite images used as mapping base.

Cyperus denudatus - Thelypteris confluens forbs

The up to 170 cm high vegetation is characterised by three dominant species *Thelypteris confluens*, *Schoenoplectus corymbosus* and *Cyperus denudatus,* which are accompanied by weeds and small Poaceae species (Figure 27). The vegetation is very dense beneath the soil surface and becomes looser at a height of 50 to 70 cm. It occurs on peat soil which is most likely to be waterlogged during the whole year and where the nutrient content is presumably relatively low. This vegetation unit indicates probably mesotrophic conditions and was only recorded in Chidi and Alemgono Wetland.

Figure 27: A *Cyperus denudatus - Thelypteris confluens* forb in Chidi Wetland (photo by C. Tegetmeyer)

Hyparrhenia dregeana - Cyperus latifolius forbs

The up to 300 cm high vegetation stands are dominated by *Hyparrhenia dregeana* (Figure 28*)*. It is accompanied by *Cyperus latifolius*, small grasses and weeds. In Alemgono Wetland the vegetation unit occurs on (partly highly decomposed) peat soil, which is apparently not water logged for the whole year and where nutrient conditions appear meso- to eutroph.

In Gojeb Wetland *Hyparrhenia dregeana* occurs also on mineral soil in large dominant stands, mainly in the southern part of the wetland. The species builds very high hummocks, what makes it difficult to walk through the dominant stands, maybe also for cattle, thus grazing is rare and occurs probably only under drier soil conditions at the end of the dry season.

Figure 28: A *Hyparrhenia dregeana - Cyperus latifolius* forb in the southern Gojeb Wetland (photo by F. Mundt)

Cyperus latifolius - Schoenoplectus corymbosus forbs

The vegetation of this unit is dominated by *Cyperus latifolius* and *Schoenoplectus corymbosus*, grasses are also frequent (Figure 29). The vegetation is 200 cm high on average. It occurs on peat soils with more or less eutrophic conditions. Although it could not be observed during field work, the vegetation is grazed when conditions become dry, given that species indicating grazing like *Floscopa glomerata* and Poaceae occur in considerable quantities. This assumption was confirmed for the Alemgono Wetland by local people.

Figure 29: A *Cyperus latifolius - Schoenoplectus corymbosus* forb in Alemgono Wetland (photo by F. Mundt)

Cyperus latifolius - Ludwigia abyssinica forbs

The mainly by *Cyperus latifolius* dominated vegetation stands are between 150 and 250 cm high and species diversity is rather low (Figure 30). *Cyperus latifolius* leaflets grow very dense and are partly mixed with already dry and dead leaves. These dominant stands are regularly interspersed with *Ludwigia abyssinica* and a few other weeds. This unit occurs on partly superficial highly decomposed peat soils. The sites are nutrient rich (eutroph). These stands are traditionally used by locals to cut *Cyperus latifolius* for roof thatching.

Figure 30: *A Cyperus latifolius - Ludwigia abyssinica forb* in Chidi Wetland (photo by F. Mundt)

Cyperus latifolius – Berula erecta edge vegetation

The edge vegetation of Chidi Wetland, limited by steep slopes, is dominated by *Cyperus latifolius* and *Berula erecta* (Figure 31). It is on average 170 cm high. Important attenders are *Persicaria decipiens* and *Impatiens ethiopica*. The sites are influenced by fluctuating water tables caused by surface runoff and the superficial peat soil is highly decomposed. Grazing was not observed during field work and is not recommended because of the toxicity of *Berula erecta*.

Figure 31: *Cyperus latifolius – Berula erecta* edge vegetation in Chidi Wetland (photo by C. Tegetmeyer)

Arundo donax - Melanthera scandens forbs

Vegetation dominated by *Arundo donax* occurs in very high (up to 300 cm) and dense stands interspersed with *Melanthera scandens* and *Persicaria setusola* (Figure 32). It was only found in Gojeb Wetland on mineral soils. Grazing is expected later in the dry season and was not observed during field work even on sites which were already dry.

Figure 32: *Arundo donax- Melanthera scandens* forb in Gojeb Wetland (photo by C. Tegetmeyer)

Cyperus latifolius - Floscopa glomerata pasture

Lower stands of up to 100 cm height dominated by *Cyperus latifolius* and accompanied by weeds like *Floscopa glomerata* and *Hygrophila schulli,* as a result of intensive grazing influence (Figure 33). The vegetation unit occurs in the Alemgono Wetland on seasonal wet sites with mineral or highly decomposed peat soil. This vegetation unit results from periodical grazing. Grazing intensity increases throughout the dry season evocating a permanent lowering of the average vegetation height.

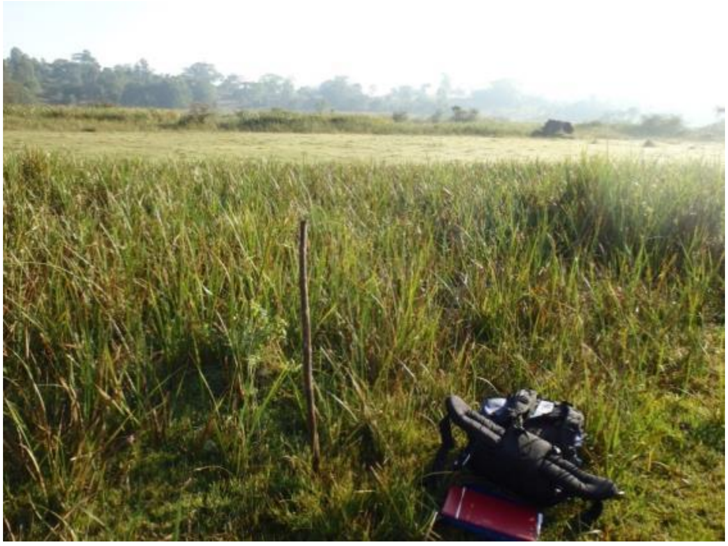


Figure 33: *Cyperus latifolius - Floscopa glomerata* pasture in Alemgono Wetland (photo by C. Tegetmeyer)

Cyperus latifolius - Vigna pakeri pasture

This vegetation unit occurs in Gojeb Wetland and is equivalent to *Cyperus latifolius - Floscopa glomerata* pasture, occurring on pastures in Alemgono Wetland. It is dominated by *Cyperus latifolius* but accompanied by a higher number of pastoral weeds (Figure 34). Due to the already high grazing pressure the occurring species were damaged, thus it was not possible to determine a large part of them. The stands reached an average height of 60 cm in December during field work, but will be lowered during the ongoing grazing season. It only develops under the stable influence of grazing activity and can be regarded as secondary vegetation.

Figure 34: Cyperus latifolius – Vigna pakeri pasture (photo by C. Tegetmeyer)

Centella asiatica meadow

Wetland sites with a very high grazing impact were already intensively grazed to a height of 5 cm during the field survey. The occurring secondary vegetation is dominated by *Centella asiatica* attended by cropped grasses and Cyperaceae (Figure 35). The sites are shortly seasonally inundated and already felt dry in December. It was observed on mineral soil in Alemgono Wetland.

Figure 35: Centella asiatica meadow in Alemgono Wetland (photo by C. Tegetmeyer)

Table 11: Overview of the defined vegetation and mapping units and the derived environmental conditions

	1	2	3	4	5	6	7		8
map unit	*Cyperus denudatus* forbs	*Hyparrhenia dregean* a forbs	*Schoenoplectus corymbosus* forbs	*Cyperus latifolius* forbs	edge vegetation	*Arundo donax* forbs	*Cyperus latifolius* pasture		*Centella asiatica* meadow
vegetation unit	***Cyperus denudatus - Thelypteris confluens* forbs**	***Hypharrhenia dregeana - Cyperus latifolius* forbs**	***Cyperus latifolius - Schoenoplectus corymbosus* forbs**	***Cyperus latifolius - Ludwigia abyssinica* forbs**	**Cyperus latifolius - Berula erecta edge vegetation**	***Arundo donax - Melanthera scandens* forbs**	***Cyperus latifolius - Floscopa glomerata* pasture**	***Cyperus latifolius - Vigna pakeri* pasture**	***Centella asiatica* meadow**
soil	peat					clay			
water	water logged		seasonal wet		fluctuating	seasonal ephemeral inundated			
hemeroby	oligohemerob					ahemerob / oligohemerob	euhemerob		
grazing	no						high		very high
trophie	mesotroph	meso-/eutroph	eutroph						
use	- seasonal grazing	- grazing?	- seasonal grazing?	- grazing? - cut and carry		- grazing? - raw material - handicraft	- grazing	- grazing	- grazing
occurence	Chidi Alemgono -	- Alemgono Gojeb	Chidi Alemgono -	Chidi Alemgono Gojeb	Chidi Alemgono -	- - Gojeb	- Alemgono -	- - Gojeb	- Alemgono -

Map units

From our analysis we derived 8 map units for more clarity on the maps and in the legends (Table 12).The map units correspond largely to the vegetation units, except for vegetation units 7 and 8, which were unified to a single unit indicating *Cyperus latifolius* pastures. The two classes were merged because they could not be distinguished doubtlessly on the mapping base.

Table 12: Identified vegetation units and the corresponding map units

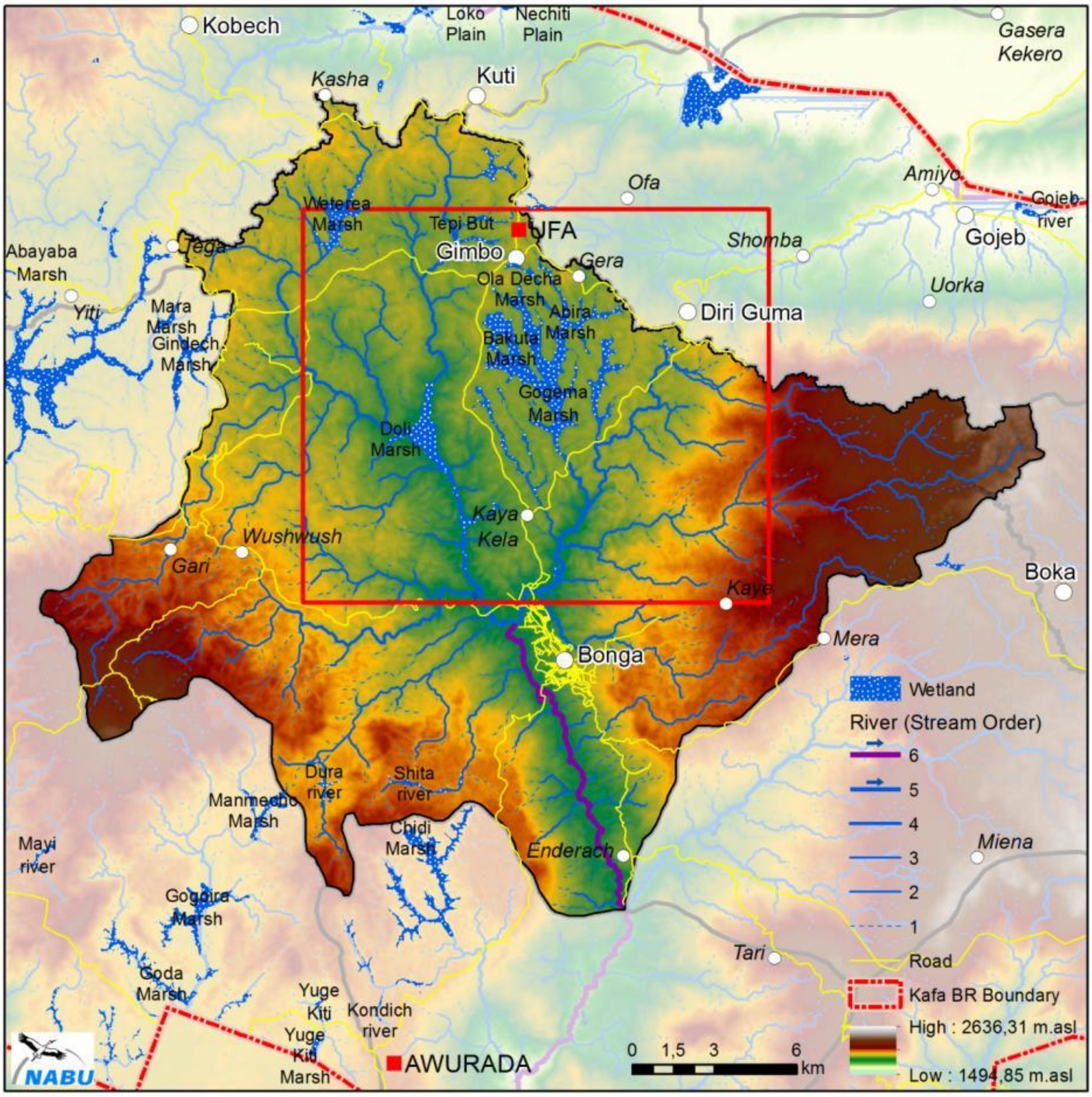
vegetation unit	map unit
1. *Cyperus denudatus - Thelypteris confluens* forbs	1. *Cyperus denudatus* forbs
2. *Hyparrhenia dregeana - Cyperus latifolius* forbs	2. *Hyparrhenia dregeana* forbs
3. *Cyperus latifolius - Schoenoplectus corymbosus* forbs	3. *Schoenoplectus corymbosus* forbs
4. *Cyperus latifolius - Ludwigia abyssinica* forbs	4. *Cyperus latifolius* forbs
5. *Cyperus latifolius - Berula erecta* edge vegetation	5. edge vegetation
6. *Arundo donax - Melanthera scandens* forbs	6. *Arundo donax* forbs
7. *Cyperus latifolius - Floscopa glomerata* pasture	7. *Cyperus latifolius* pasture
8. *Cyperus latifolius - Vigna pakeri* pasture	
9. *Centella asiatica* meadow	8. *Centella asiatica* meadow

a. Alemgono

According to the topographic maps (0735B4/ETH4, 0736C1/ETH4, 1: 50,000; EMA) Alemgono Wetland consists of Bakuta Marsh, Ola Decha Marsh, Abira Marsh (upper to middle wetland), and Gogema Marsh (lower wetland). The northern part of Alemgono wetland is the water divide of the basin to the neighbouring watershed. The road between capital Ufa and town Diri Guma passes along the ridge. A road from Kaya Kela to Gimbo on the west side of Alemgono Wetland, serves as an artificial watershed while separating surface water draining either to the west side of the road to Doli Marsh or to Bakuta Marsh in Alemgono wetland. The road runs parallel to the river Gincha. Pour points from Alemgono exist only on the eastern side (framed by the rough road Diri Guma to Kaya Kela) accumulating to the river Shoka and Gogema. Hence, the boundary of Alemgono wetland is demarked by roads, forming a triangular shape reducing to the pour points in the south. In the North, the relief is more inclined and the terrain surface is transversed by discharge paths, which lead rain water to the southern part of the wetland. Streams are short and fast in nature and it is likely that they have a highly erosive potential. In the south, the terrain relief is homogenous; terrain is less inclined and can be described as a lower depression. Rivers and streams are not clearly distinguishable because water accumulates in this depression. In these parts of the wetland, the highest infiltration is expected and permanent water logging supports the accumulation of organic material. Alemgono wetland is composed of different hydrological sub-units, which results in different sites and habitats. Depending on the precipitation intensity during the rainy season and the height of the corresponding water level in the subsequent dry season, pasturing is constantly progressing from the wetland edges into the central areas. However, the direct influence of current and past land use is difficult to determine because every hydrologic subunit shows a specific behaviour in response to rainfall and run off, hence the variation within Alemgono is dependent on multiple factors. Alemgono wetland covers an altitudinal rage of 1,641 m.a.s.l.up to 1,765 m.a.s.l..

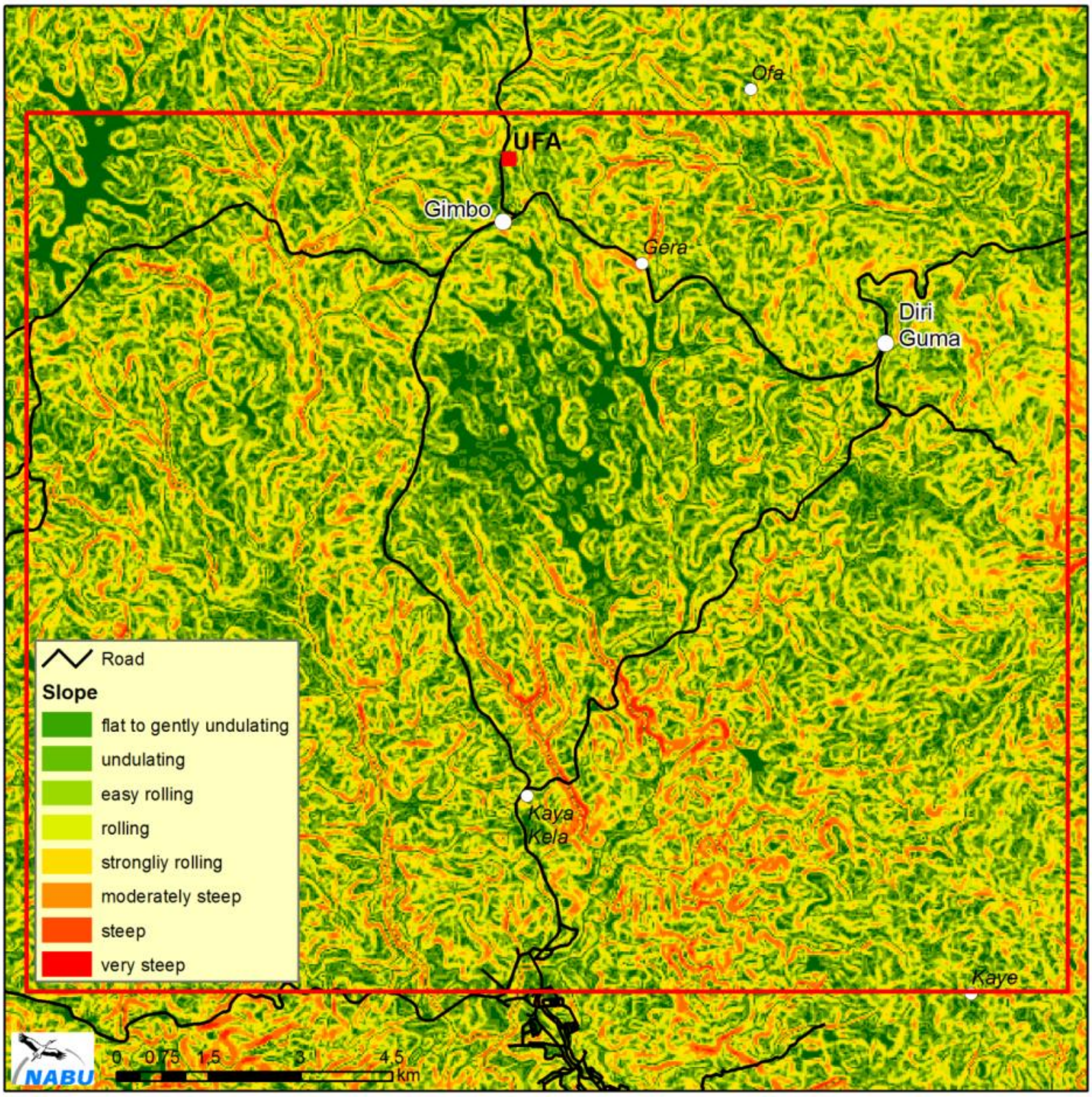
i. Hydrology/ Topography

Alemgono wetland is situated in the same sub-basin of Omo-Gibe river basin as the administrative center Bonga. The sub-basin has a total area of 617 km² and an altitudinal range from 1495 m.a.s.l. up to 2,635 m.a.s.l.. Alemgono wetland is one of the main contributors of surface and sub-surface run-off from the sub-basin (Map 11). Beside Alemgono wetland, there are two smaller wetlands, namely Doli marsh and Weterea Marsh. This highlights the importance of Alemgono wetland as a water retention sink. Generally, the Kafa Biosphere Reserve is fed by 4 main rivers – Gojeb river, Meni river, Woshi, and Dincha. Alemgono Wetland plays a major role for the receiving water course Dincha, due to the fact that the river Gogema (headwater rise from Alemgono) is one of the main tributaries. Dincha is the only pour point of the sub-basin.



Map 11: Sub-basin of Alemgono Wetland

The sub-basin has a pronounced dendritic drainage with a compact shape accumulating to the main Omo river towards the Lake Turkana. The pronounced dendritic drainage pattern is formed due to homogenous lithology and structural controls. Water runs from north to south and passes Bonga town. Alemgono wetland is situated at the northern edge of the sub-basin. The slope gradient map for the Alemgono sub-basin indicates, that within the Alemgono wetland, slope rages from flat areas up to steep slopes (Map 12). Moderately steep slopes can be found to a minor extent in the north of Alemgono wetland, traversed by 1st order streams often buffered by trees. Steep and very steep slopes at the pour points in the south of Alemgono wetland are mainly covered with forest. The centre of Alemgono wetland is situated in a topographic depression, which is flat to easy rolling with some outcrops covered by agriculture or without vegetation. Water from precipitation and groundwater discharge accumulate in the so called Gogema Marsh (Map 11). Due to the position in the landscape with bordering artificial and natural watersheds, we expect only a minor surface flow from adjacent uplands. In Alemgono wetland there are no significant inflows (except Shoko river in the north-east).



Map 12: Slope gradient map of Alemgono wetland (red square identifies the map extract showing Alemgono wetland)

To be able to compare all study sites, all values are based on the modelled sub-basin. The morphometric characteristics of the Alemgono sub-basin are summarized in

Table 13.

Table 13: Morphometric parameters of Alemgono sub-basin

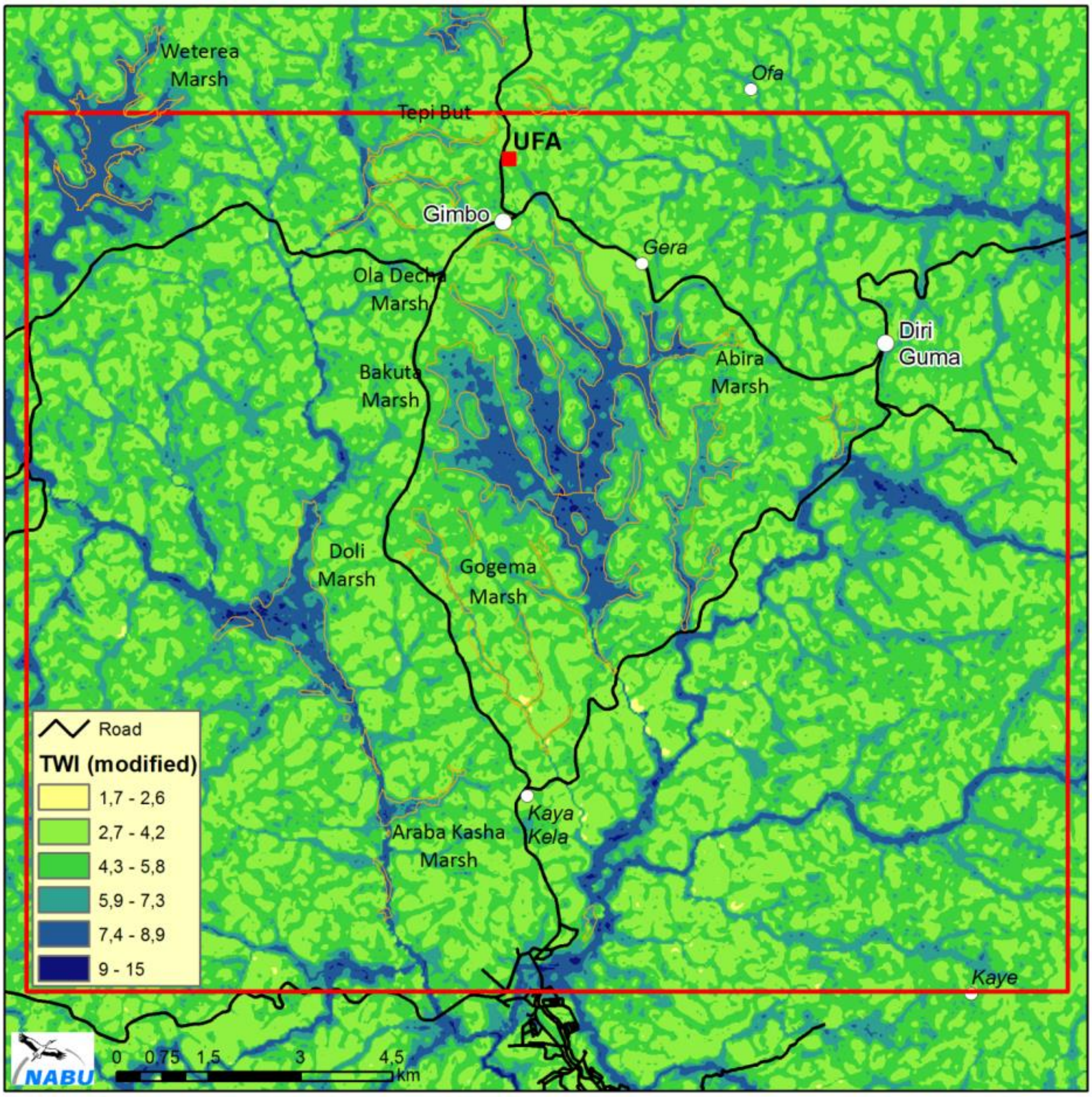
Order of Stream	Number of Streams	Bifurcation Ratio	Total Stream length [km]	%	Average Stream length [km]	Length Ratio
I	506		456,956049	50,4101513	0,90	
II	111	4,56	220,673339	24,3440839	1,99	2,20
III	25	4,44	136,356955	15,0425293	5,45	2,74
IV	7	3,57	60,674449	6,69344057	8,67	1,59
V	1	7,00	17,127823	1,88949496	17,13	1,98
VI	1	1,00	14,687634	1,62029993	14,69	0,86
Σ	651		906,476249			
Ø		4,1	1,4			1,87

The morphometric parameters of Alemgono sub-basin are not statistically significant different from the overall estimation of the Kafa BR (Table 2). But the mean length ratio show a smaller range than for the whole Kafa BR (0.86 – 2.74) which indicates less variation in the terrain.

The drainage density with 1.5 km/km² is lower than the average within the Kafa BR (1.8 km/km²). A basin with low drainage density is often found to be poorly drained with a slow hydrologic response(Yildiz 2004). Hence, the lower drainage density is explicable by the relatively high share of wetlands (thus retention areas) and the moderate relief (mean slope 10%) in the sub-basin. The surface water, if occurring, follows a gradient from north to south.

For the purpose of wetland delineation but also for descriptive use, the topographic wetness index (TWI) was calculated. The TWI was derived from the interpolated DTM and can be used to predict soil moisture. We found that the TWI is not sufficient for modelling relatively flat areas (depression in Alemgono, and Gojeb lowland), thus we decided to apply a modified algorithm – similar to the TWI[21] – but more robust against flat areas. The SAGA wetness index (SWI)(Boehner et al. 2002) models the overland flow more realistically. The limitation of SWI is related with missing adaptation possibilities like vegetation cover, lithology, geologic distortions or other soil parameters. The formation of wetlands and the hydrologic budget are directly linked to these parameters. Thus, deviation of modelled moist areas can locally occur.

[21] It is based on a modified catchment area calculation, which does not presume oft he flow as a very thin film. As result it predicts for cells situated in valley floors with a small vertical distance to a channel a more realistic, higher potential soil moister compared to the standard TWI calculation.



Map 13: Topographic Wetness Index (modified after Boehner et. al) for Alemgono Wetland (red square identifies the map extract showing Alemgono wetland)

The derived topography index depicts all pilot sites, delineated quite well from satellite imagery interpretation. Only some boundaries were adopted after the verification in field. Additionally, riverine fens which are difficult to detect by image interpretation (due to dense crown cover) could be detected and these sites were included into the flora assessment. Channelled outflows are visible on the east side between Diri Guma and Kaya Kela town. As the elevation contours are closed on the west side (artificial boundary from road construction), and on the north side (natural boundary – ridge), surface water accumulates in the southern part of the wetland (mainly Gogema Marsh) (Map 13), which is the centre of the depression.

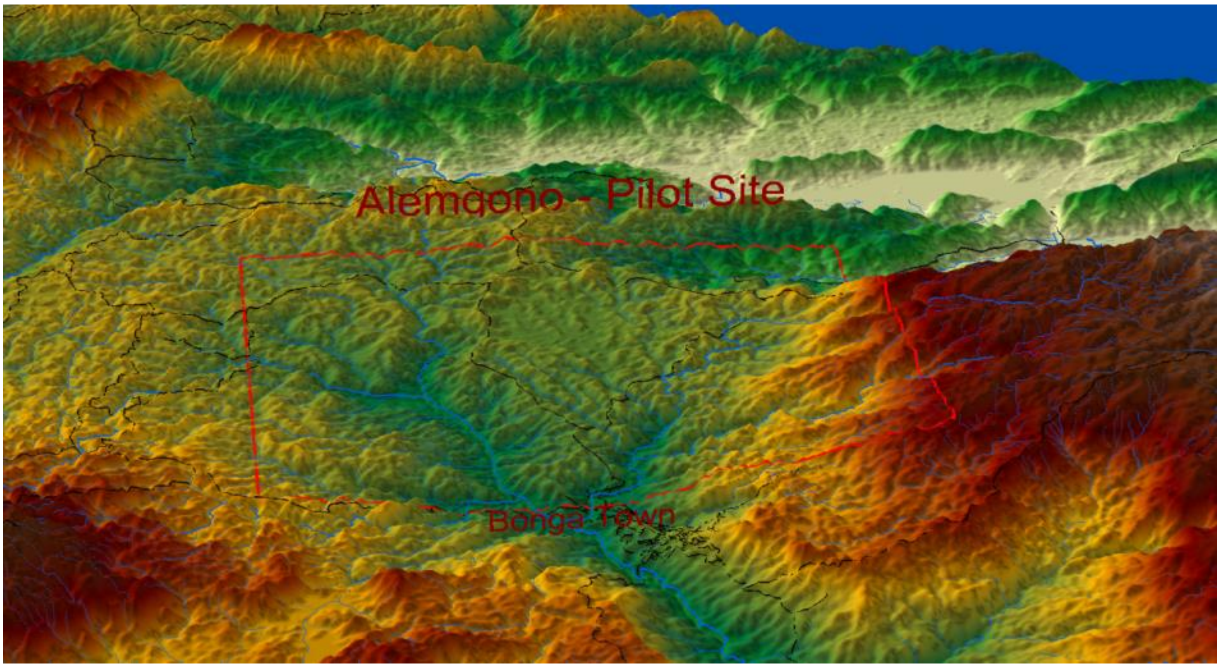


Figure 36: 3D view of Alemgono with modelled stream network (blue) and roads (black) (height extrusion by factor 3)

The position in the landscape and an absence of channelled inflow implies high interflow from adjacent uplands – Socha ridge - in the east of the wetland. The only channelled outflow is recorded on the east side of Alemgono with the river Gogema and a stream 1 km to the north. Both streams were carrying small amounts of water during the field visit in March (end of dry season). It cannot be ruled out that there are a few more intermitted streams during the rainy season, draining the Alemgono wetland.

It is very likely that Alemgono Wetland is mainly fed by groundwater and precipitation; due to the fact that there are no permanent tributaries and no significant crop-out of springs. Furthermore, the wetland is located in a distinct morphologic sink (Figure 36). The variation of precipitation and even low water removal for activities, directly affect the water table of Alemgono[22], which indicates that rainfall is elementary for the saturation of the wetland. Due to a strong anthropogenic influence in the wetland, it is unclear if the strong fluctuating water table during dry and rain season results from a loss of retention capacity caused by degradation; or if this is due to the minor importance of groundwater inflow. Probably, it is a mixture of both. Anyhow, the hydrodynamic can be described by seasonal vertical water level fluctuation that results mainly from evapotranspiration, a lack of precipitation, downward seepage into Gogema river and to some extend due to human activity.

According to the hydrogeomorphic classification system, Alemgono wetland can be classified as wetland depression with vertical fluctuation with two channelled outflows, which is fed mainly by rainwater and probably groundwater influenced.

[22] The finding of an oscillating water table was one main result of group discussions and expert interviews in and around Alemgono. Additionally, 2 field visits in different seasons (March – end of dry season) – most of the wetland was passable; and December (start/ mid of dry season) – especially Gogema Marsh was not passable, support this finding

ii. Vegetation

The north-eastern part of Alemgono Wetland is dominated by Centella asiatica meadows (see Map 4) which develop under the influence of intensive grazing. Cyperus latifolius - Floscopa glomerata pastures and Cyperus latifolius-Ludwigia abyssinica forbs occur in the trenches due to a higher water level and a resulting less intense grazing. Those forbs lead over to Cyperus latifolius-Schoenoplectus corymbosus, Hyparrhenia dregeana - Cyperus latifolius forbs and further Cyperus latifolius - Ludwigia abyssinica forbs in southern Alemgono Wetland, where the water table is higher year-round and peat soils can develop.

Table 14: Vegetation & Map Unit for Alemgono pilot site

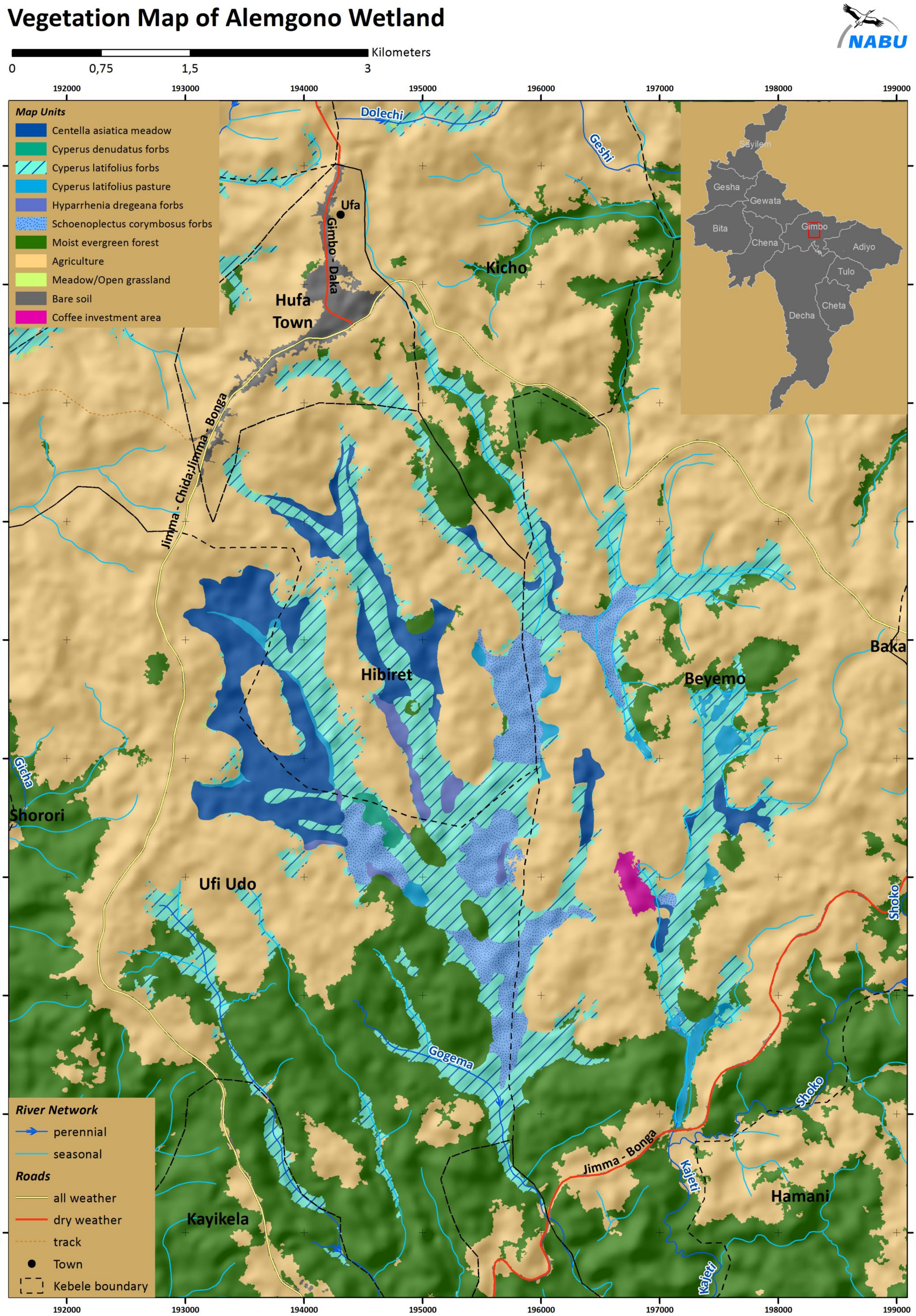
Vegetation unit	Map unit	Area in ha
***Centella asiatica* – meadow**	Centella asiatica meadow	213,01
***Cyperus denudatus - Thelypteris confluens* forbs**	Cyperus denudatus forbs	7,62
Cyperus *latifolius - Ludwigia abyssinica forbs*	Cyperus latifolius forbs	1012,44
***Cyperus latifolius - Floscopa glomerata* pastures**	Cyperus latifolius pasture	40,17
***Hyparrhenia dregeana - Cyperus latifolius* forbs**	Hyparrhenia dregeana forbs	20,60
Cyperus latifolius-Schoenoplectus corymbosus forbs	Schoenoplectus corymbosus forbs	148,10

Table 15: Species list and site description for Alemgono pilot site

species	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Hygrophila schulli	Acanthaceae	moist depressions, marshy places					
Berula erecta	Apiaceae	marshy area	x			shallow water	
Centella asiatica	Apiaceae	damp grassland, swamp		x	x		
Ageratum conyzoides	Asteraceae	woodland,fields,roadsides, garden		x	x		
Melanthera scandens	Asteraceae	swamp margins, river banks	x		?		
Impatiens ethiopica	Balsaminaceae	river stream bank,swamps marshes, ditches, damp spots					
Floscopa glomerata	Commeliaceae	damp meadows, ditches, boggy grassland		x	x		grazing weed
Cyperus denudatus	Cyperaceae	swamps, swamp-edges, ditches, wet habitats	x			wet	peat formation
Schoenoplectus corymbosus	Cyperaceae	Wet habitat, swamps, pools, lake margin	x			standing water	peat formation
Cyperus latifolius	Cyperaceae	Swamp	x			wet ground	raw material, roof thatching
Phyllanthus boehmii	Euphorbiaceae	marshes, swampy grassland, wet banks	x				
Vigna pakeri	Fabaceae	grassland, woodland,forest margins, cultivations		x	x		
Plectrantus edulis	Lamiaceae	marshy areas or cultivated	x				grazing weed
Pycnostachys recurvata	Lamiaceae	marshy,moist ground	x				grazing weed
Urticularia stellaris	Lentibulariaceae	damp, shallow soil				submerged	
Dissotis canescens	Melastomataceae	seasonally water-logged grassland, wet flushes	x			water logged	
Epilobium salignum	Onagaceae	marshy, swampy places	x				
Ludwigia	Onagraceae	swampy ground, near	x				

abyssinica		rivers lakes					
Hyparrhenia dregeana	Poaceae	seasonally damp depressions, open grassland stony hillsides				seasonally moist/wet	grazing ?
Persicaria strigosa	Polygonaceae	marshy ground, swamps, lake shores, wet grassland					
Persicaria limbata	Polygonaceae	rivers, streams				in water	
Persicaria decipiens	Polygonaceae	roads, river banks					
Alchemilla pedata	Rosaceae	moist groun, grassland	x				
Galium scioanum	Rubiaceae	damp wet swampy places					
Crepidorhopalon whytei	Scrophulariaceae	montane swamps	x				
Thelypteris confluens	Thelypteridaceae	swamps,floating bogs?	x			wet	peat formation

Vegetation Map of Alemgono Wetland



Map 14: Vegetation Map of Alemgono Wetland

iii. Soil

The higher located floodplains in the North of the wetland (described as Bakuta Marsh, Ola Decha Marsh, and Ariba Marsh) are characterized by mineral soils, the areas are flooded only during the rainy season. Later the water flows quickly into the central discharge paths, characterized by alluvial soils with high organic proportion or under wetter conditions by organic soils with highly decomposed peat, which constitute the transition between seasonal to all year round wet sites, where peat soils with high water holding capacity occur. Considerable peat stocks are expected in the southern part of the wetland (Gogema Marsh).

iv. Hemeroby/ Threats

The natural division of Alemgono into a drier northern part and a wetter southern part impinges on different hemeroby classes. The northern part is in most parts euhemerob, due to the intensive grazing that follows the lowering water level after the rainy season. The natural vegetation is replaced by vast Centella asiatica meadows in large areas. Approaching form the north towards the central depression, the wetland can be classified as mesohemerob. Oligohemerob areas are found only in the southern part, where the high water level reduces the presence of human or livestock intruders.

Due to the fact that the upper wetland has a fast response on the vertical water fluctuation, an absence of precipitation and is easy accessible from uphill settlement, here grazing intensity is high and the vegetation is already grazed to a few centimetres in December (mid dry season). The grazing pressure widens with the continuous drying of surfaces of the discharge trenches up to the middle wetland. It is assumed, if grazing pressure rises, it also takes place at permanently wet peat soils in the lower wetland.

Main threats leading to a degradation of the ecosystem and ecosystem services in Alemgono wetland are overgrazing and the conversion of wetland area into arable land (Map 15).

During GD and IDI, the local communities indicated the shortage of agricultural land, caused by degraded productivity. If this trend continues in conjunction with an increasing food demand, it is likely that the upper wetland will be completely converted to agriculture. Considering the hydrodynamic of Alemgono with seasonal vertical water fluctuation, this will result in a downslope encroachment towards the lower wetland. Furthermore, the relatively steep terrain in the upper wetland (Map 12) is susceptible to landslides if vegetation cover is shallow rooted.

The overgrazing leads, besides the loss of the PNV, to soil compacting and erosion, gullying, the loss of ground cover and may cause nutrient discharge. Especially in the western part (Bakuta Marsh) different gullies were observed (Figure 37). The Tropical Livestock Unit of the surrounding Kebeles is low – medium (Map 27). But the surroundings of Alemgono wetland is dominated by agriculture or wetlands embedded in steep slopes (e.g. Doli Marsh) which results in a high livestock number within Alemgono. The present Tropical Livestock Unit is estimated at 4 – 10 per hectare, which is 2 to 5 times the carrying capacity estimated for Sub-Saharan highlands(Pica-ciamarra et al. 2007). The expert interviews revealed that the number of livestock is influenced by an inefficient land tenure system, which provides livestock keepers with incentives for accumulating animals. According to in-depth interviews, each household in Alemgono wetland hold 4 -5 cattle!

Soil erosion – Gullying in Bakuta Marsh (36°13'13,312"E 7°21'46,475"N)

Soil erosion – Gullying in Bakuta Marsh (36°13'40,886"E 7°21'48,367"N)

Figure 37: Soil erosion due to overgrazing in Alemgono wetland

Considering the main water source of Alemgono wetland, the intense grazing with soil compaction leads to a reduced infiltration capacity which thus intensifies seasonal variation of water availability. Additionally, the retention function might be lowered due to missing water availability caused by higher evapotranspiration and higher outflow. Of interest, are some results of a chemical soil analysis in Alemgono (unpublished, E. Dresen 2014), which reveal that the presence of livestock and/ or intense agriculture have a strong impact on the soil. In this analysis it was clearly visible that the typical wetland soil properties get lost (very low C_{org}-content). A similar finding of wetlands soil degradation through human activity is also described in Mekonnen and Aticho(Mekonnen & Aticho 2011).

The use of fertilizer on the surrounding Kebeles of Alemgono could possibly lead to eutrophication, salinization and hence to the loss of the potential natural vegetation. Furthermore, habitat fragmentation and a loss of biodiversity can be expected. Due to its position in the landscape, it is believed that the fertilizer deposit in Alemgono wetland is medium.

In the lower wetland leading to the outflow close to Kaja Kela, forests are present which might be affected by deforestation in the future. During Group discussion and in-depth interviews, the lack of firewood in the future was stressed as a major threat. This could alter the general function of

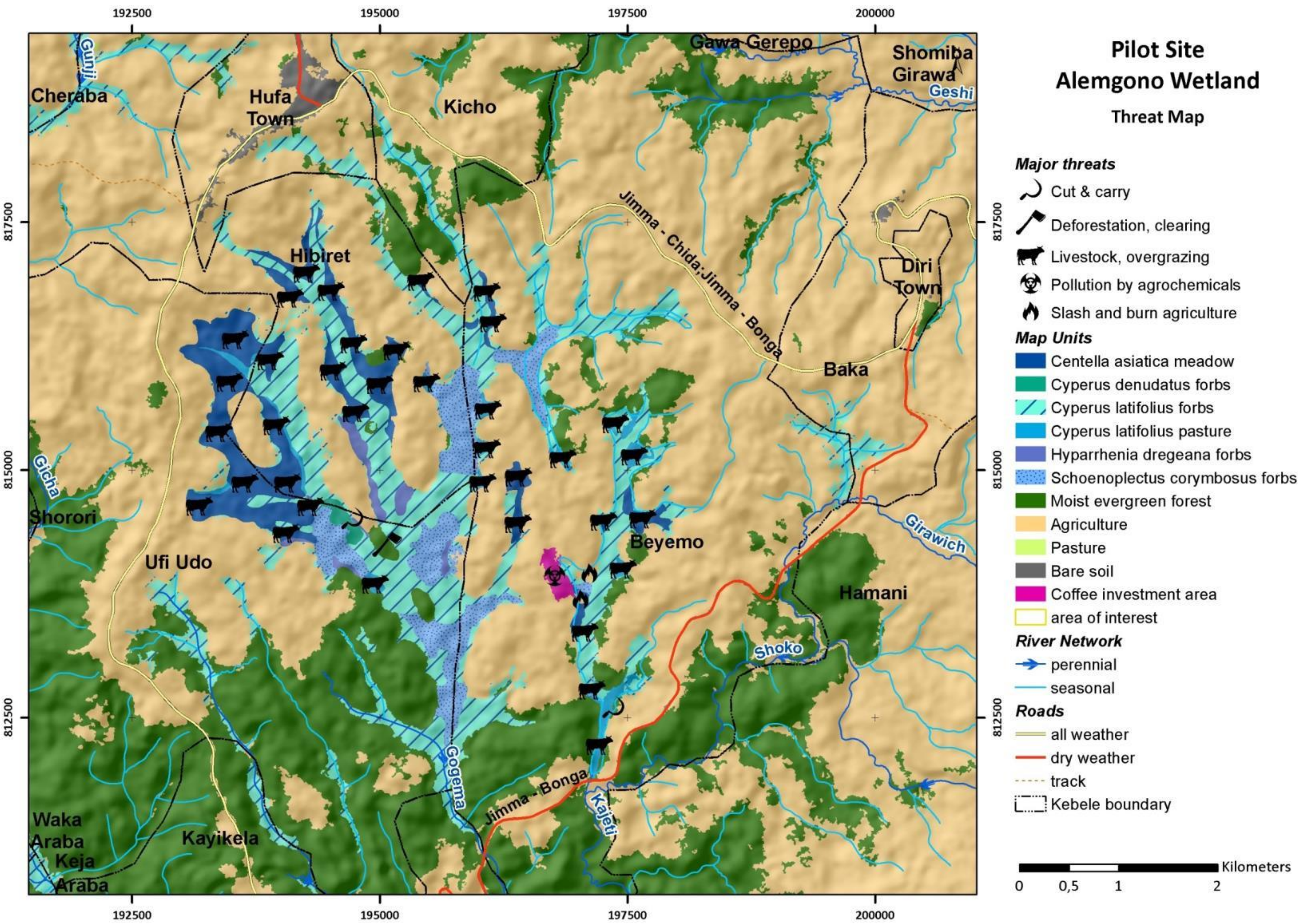
Alemgono wetland as a water sink because the infiltration rate will be affected and a higher surface flow to the next tributary could turn Alemgono wetland towards a flow-through system.

The use of the so called Koho by cut & carry, does not severely affect the wetland or its vegetation, since it represents only a minor interference.

During the field visits and information from IDI and GD it could be revealed that irrigation schemes using pumps are uncommon practice. Furthermore, the brick factory on the west side of Alemgono wetland (36°13'12,256"E | 7°21'54,496"N) is abandoned (key informant W. Woldemariam; confirmed by field visit). So far, there are no large scale agricultural investments present except for a coffee investment area (CIA) of about 10 ha on an outcrop in the middle wetland (Gogema marsh; 36°15'16,456"E 7°21'11,249"N). The PNV on these outcrops is identified as Afromontane forest, naturally hosting scattered wild coffee. Hence, CIA can be defined as mesohemerobic, which as such is not a threat to the wetland. More likely is an impact due to agrochemicals applied for higher yields and to suppress weeds.

Figure 38: Coffee investment area in Alemgono wetland (photo M. Gemeinholzer)

According to in-depth interviews, the main thread for Alemgono wetland is the insecure land tenure, which of course is at the one hand a direct threat wto the local communities but also an indirect but important threat to the wetland and its biodiversity. Because it leads to an undirected, illegal use of ecosystem services and is combined with unsustainable practices. This finding coincides with the online questionnaire, which states that a legal framework for wetland is lacking in general.



Map 15: Threat Map, Alemgono Wetland

v. Management/ Monitoring

Alemgono wetland acts as regulators of flow, storing water during the wet season and releasing it during the dry season, thereby maintaining dry season river flows of Gogema which is a main tributary of Kajeti river in the east side of the wetland. Since the Kajeti River is the main water supply for Bonga town, this would seem to be a very important hydrological function of the wetland and one that should not be put at risk by changing the land use within the wetland. Further research and monitoring is needed to quantify the water amount coming from Alemgono wetland contributing to the water supply of Bonga town.

Endangered bird species like the Wattled Crane (Bugeranus carunculatus) (IUCN 2012, Vulnerable) have been partly observed in intensively grazed sites of Alemgono Wetland. Ornithologists, who were present at the same site during field work, confirmed a breeding site of the species in lesser disturbed higher vegetation. The Wattled Crane uses different habitats of the wetland for different activities, including sites which are extensively modified (high alteration form its PNV). Special feeding, breeding and resting habitats are necessary for the suitability of an area for habitation. After Johnsgard(Johnsgard 1983) the preferred nesting sites are where grass and sedge marshes are bordered by drier, flat to sloping grassland meadows, with medium height vegetation and water up to 1m in depth. In higher and denser stands of Cyperus latifolius the also endemic Rouget's rail (Rougetius rougetii) was observed on edges and cattle pathways.

Considering the ecological importance as habitat for bird species, it is important to maintain the cultural landscape in Alemgono without intensification. The presence of vulnerable but hemerophile species highlights the complexity and the importance of evaluating ecological hazards interdisciplinary.

The forest at the southern edge of the wetland plays a major role in the hydrodynamic of degraded parts of Alemgono wetland. As the terrain of Alemgono is slightly inclined from north to south, beside vertical water level fluctuations, a minor unidirectional flow leads to a channelled outflow (Gogema/ Gajeti river). The surface runoff increases with higher soil compaction. The accumulated water passes the forest, which supports infiltration and deceleration of water flow. It is assumed that the forest can function as a buffer of surface runoff and helps to maintain the retention function of Alemgono wetland. Additionally, in the dry season the forest releases the grazing pressure to the wetland, as around 25% of interviewees practice forest grazing (as opposed to only 4% in the rainy season). Remarkable is the expected limited resource of all pilot sites in the future. Around 80% of all interviewees of all pilot sites named fuel wood as the most limited resource in the future. As Alemgono wetland is mainly located in a matrix of agriculture (Map 15), this concern is quite obvious. Further research should identify, if alternatives to fuel wood exist to release the pressure on the forest and to limit the plantation of draining Eucalyptus species in the wetland.

During in-depth interviews 37.3% (n=131), the participants expressed their interest to increase crop production by intensifying present cultivated areas and by expanding the area cropped[23]. The same interest was mentioned during group discussions. High population pressure of adjacent Kebeles will

[23] Question of questionnaire : "What do you paln/ or wish to do in the future?"; possible answer: "Extend farming activities" | "Extending livestock" | "Extending fishing" | "no changes" (Dresen 2014) – Table 6

amplify the conversion of wetland vegetation to agriculture. In the northern part of Alemgono Wetland, where steep slopes are present, a fast water runoff was stressed out. It seems that the lack of water in the northern part of the wetland is one major biophysical constraint for agricultural production.

The potential suitability of the biophysical condition of the wetland for crop production is seen to be good, as the lower wetland offers year round water and very fertile soils. But keeping this in relation to the amount of beneficiaries, this is not the advised development.

There is little doubt that an increase in crop production and cattle grazing would result in the ecological condition of the wetland moving towards being "less natural." While the conversion of wetland vegetation to arable land would result in a change of habitat for bird species, an intensified cattle grazing would result in further compaction of wetland soil to a final change in soil properties.

Summarizing, Alemgono Wetland has a major contribution to social welfare providing physical benefits to the whole community within Alemgono wetland and even adjacent Kebeles. As the population density is quite high around the wetland (Map 29) it is likely that the pressure on the wetland will increase. Currently, most important ecosystem benefits are stressed out with cattle grazing and watering (social benefit for communities within Alemgono and adjacent Kebeles), use of construction material (social benefit for communities within Alemgono and adjacent Kebeles), crop production (benefit for local communities), and providing drinking water for downstream Bonga town. The wetland is easily accessible with very good connections to markets, which makes it attractive for an intensified agriculture production. All households within the wetland use the natural vegetation from the wetland for different purposes. In addition, wetland soils are used for making pots and other household items.

The ecological importance of the Alemgono wetland is internationally recognized due to its importance for migrating and endemic birds(Ethiopian Wildlife and Natural History Society 1991). Alemgono wetland is attractive as a breeding and feeding ground for endemic birds, such as the Wattled Crane (Bugeranus carunculatus) and Rouget's rail (Rougetius rougetii) as well as resting sites for migrating birds like Yellow wagtail Motacilla flava and Red-throated pipit Anthus cervinus (T. Ryslavy personal comment).

As chemical soil analysis have shown (unpublished, E. Dresen 2014) that an intense grazing and conversion to agriculture lead to change in soil properties[24], it is advised to keep the balance of exploiting ecosystem services and recovering.

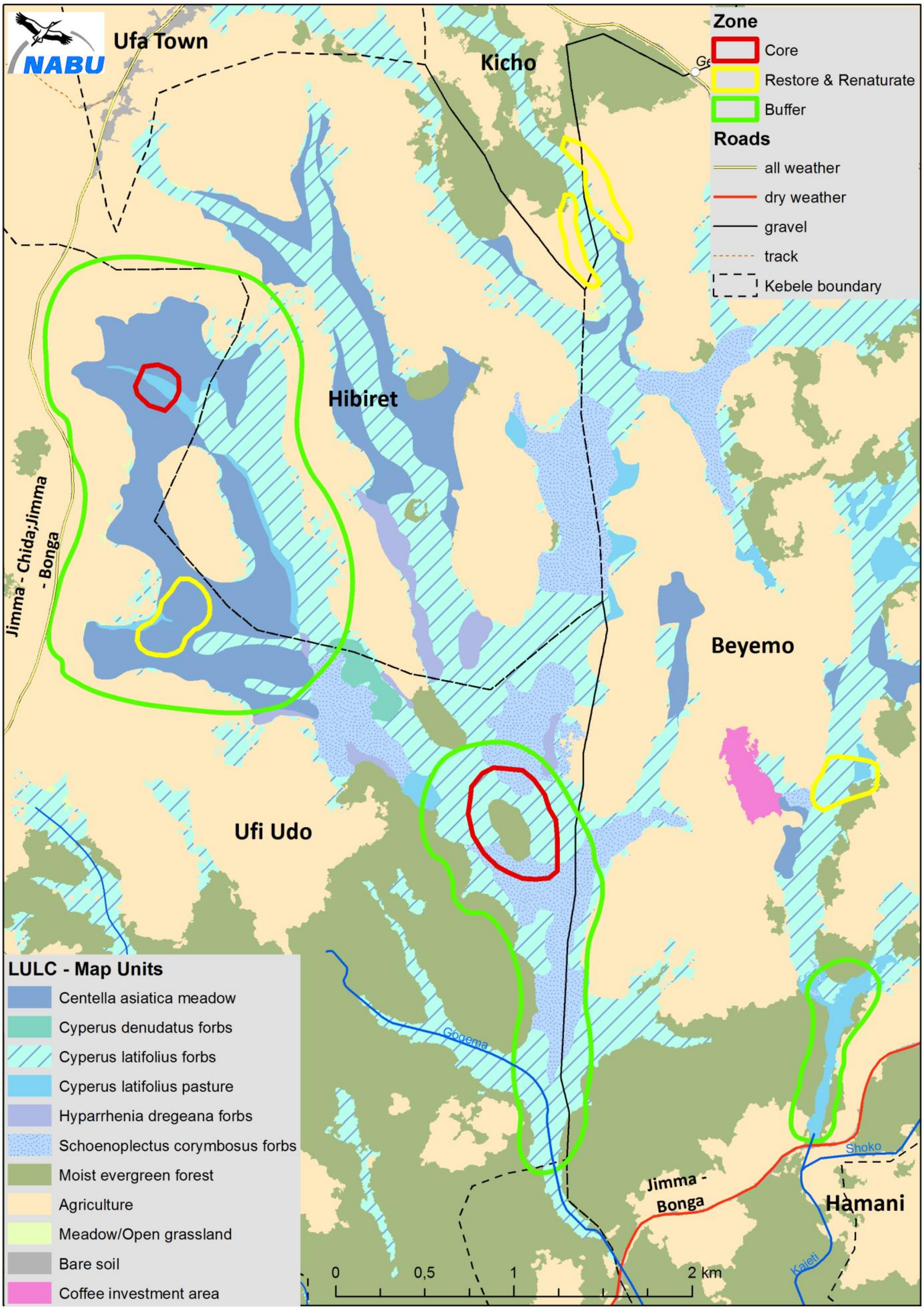
To preserve the important microhabitat structure of the Alemgono Wetland, it is required to prevent the transformation of all the area to agricultural land and a sustainable pasturing system should be maintained. Since birds are respected by the locals, they don´t show fear of human presence what raises their attractiveness for ornithologists and nature tourism. Instead of economical welfare through the expansion and intensification of agriculture, bird watching tourism should be encouraged as a source of income. The good infrastructure and the nearby Bonga town are good prerequisites. As the first initiatives from NABU (bird watching tower) were not integrated into a

[24] Percentage of organic carbon and total nitrogen content of degraded wetland soils was decreased significantly

management concept, the facilities were destroyed by community locals. We suggest setting up a bird watching committee including the community locals and create incentives to support the bird watching tourism.

Figure 39: Pair of Wattled Crane (*Bugeranus carunculatus*) in Alemgono Wetland (photo by F. Mundt)

According to collated and evaluated information, a proposal of zonation – open for discussion – will be showen below. It should be understood as a baseline for a participatory process with all stakeholders and improved by further research. A spatialization was not possible in all cases due to missing ground truths of the specific sites. Photo documentary was not available for all proposed sites, (all photos are taken during the 1st, 2nd, 3rd field visit, mid – end of dry season). The legend of the zonation overview will be valid for the detail extracts.



Map 16: Proposed Zonation for Alemgono Wetland

1. Core Zones for Alemgono

Location: 36°14'25,888"E 7°21'14,395"N | on Vegetation Map (Map 14)

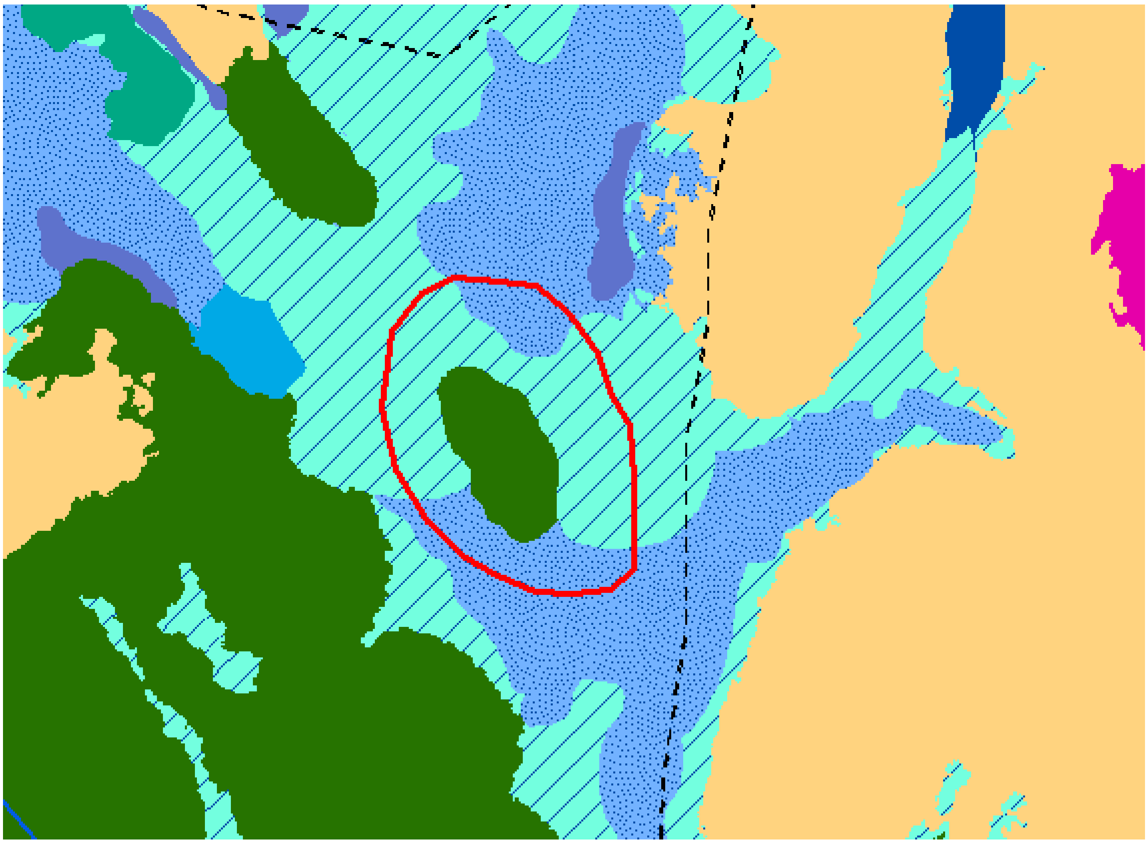


Photo of location

Present Vegetation	Cyperus latifolius - Schoenoplectus corymbosus forbs | Cyperus latifolius - Ludwigia abyssinica forbs |
Present land use	In dry season probably cut and carry (not confirmed)
Description	Protection of lower wetland with oligohemerob hemeroby (low human impact), wetland – forest complex, high water table
Function/ objective	Important breeding site, peat formation, reference site of ecological functions of wetland without human disturbance
Size [ha]	24
Kebele	Ufi Udo

Location: 36°13'25,165"E 7°22'29,315"N | on Vegetation Map (Map 14)

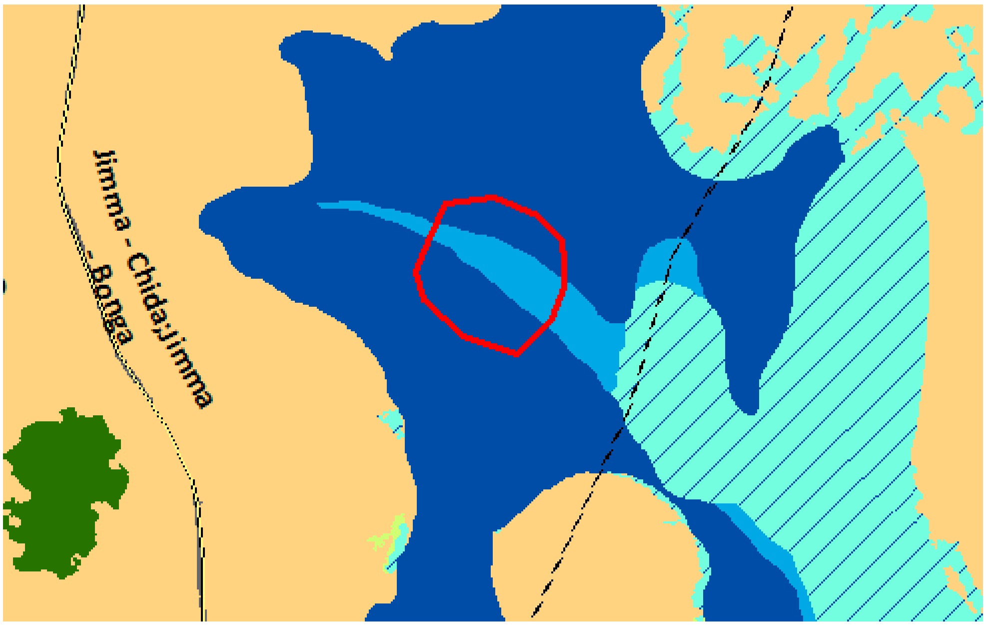


Photo of location (red square is indicating the breeding site of the Wattled Crane, high relevance for protection)

Present Vegetation	Cyperus latifolius - Floscopa glomerata pasture | Centella asiatica meadow
Present land use	Grazing area
Description	Extensive grazing area with grassy vegetation up to 1 m, moist – SWI >6<8
Function/ objective	Breeding site of Wattled Crane (Bugeranus carunculatus)
Size [ha]	5
Kebele	Ufi Udo

2. Area to restore and renaturate of Alemgono

Location: 36°13'27,712"E 7°21'45,797"N | on Vegetation Map (Map 14)

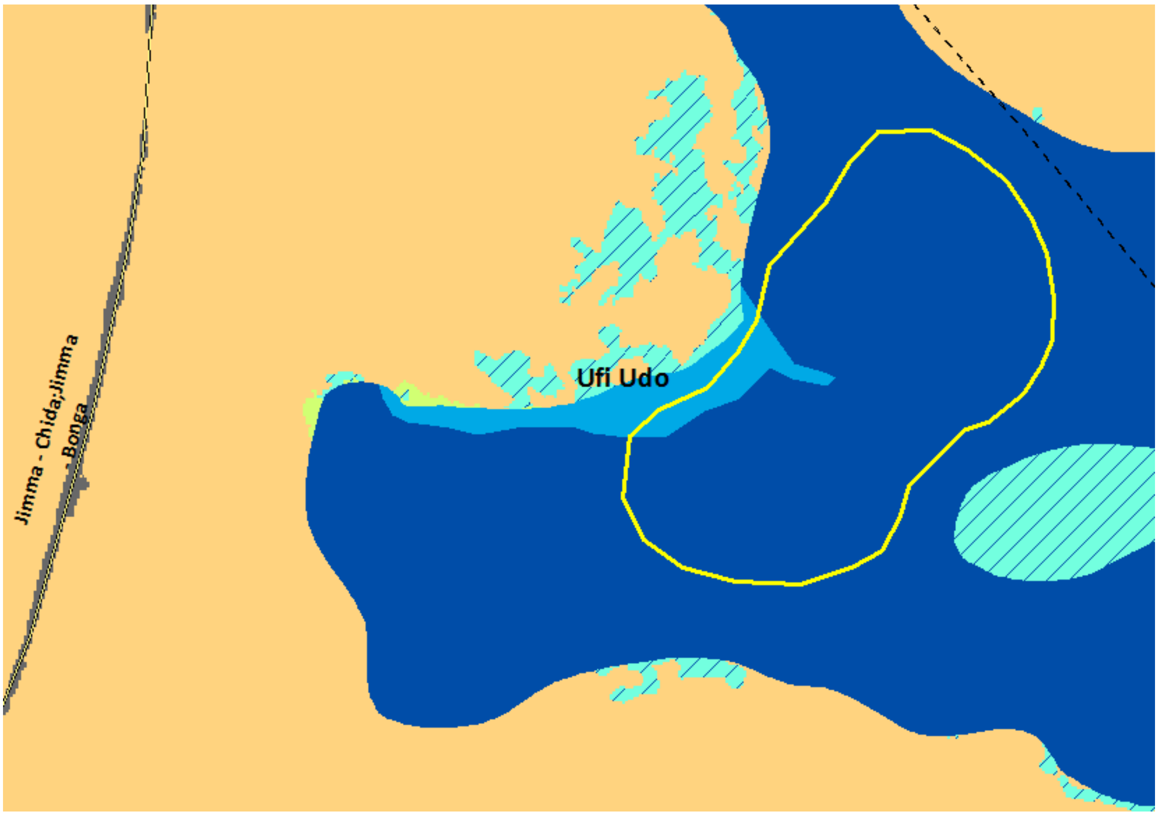


Photo of the location

Present Vegetation	Cyperus latifolius - Floscopa glomerata pasture | Centella asiatica meadow
Present land use	Intense grazing area
Description	Intense grazing area with gully erosion
Actual threat	Overgrazing, soil erosion, soil compaction,
Measure	Introduction of grazing management (in rain season – compound feeds), regulating livestock to carrying capacity of 2 TLU per ha
Size [ha]	10
Kebele	Ufi Udo

Location: 36°15'27,014"E 7°21'18,759"N | on Vegetation Map (Map 14)

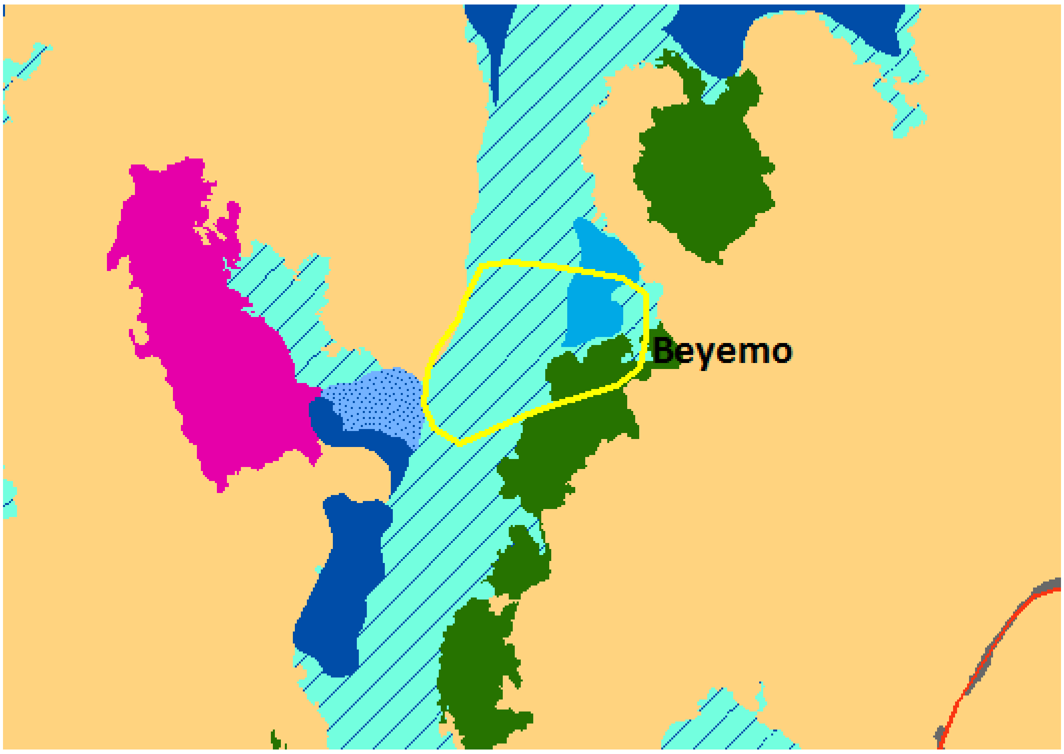


Photo of the location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus latifolius - Floscopa glomerata pasture | Cyperus latifolius - Schoenoplectus corymbosus forbs
Present land use	Intense grazing area, agriculture
Description	Intense grazing area, illegal wetland conversion to arable land
Actual threat	Overgrazing, soil erosion, soil compaction, illegal wetland conversion
Measure	Introduction of grazing management (eg fencing in rainy season), rise of additional tax for encroaching into the wetland, establish clear boundaries between wetland and agricultural land, enforce legislation concerning illegal land conversion
Size [ha]	8
Kebele	Beyemo

Location: 36°14'44,149"E 7°23'1,202"N | on Vegetation Map (Map 14)

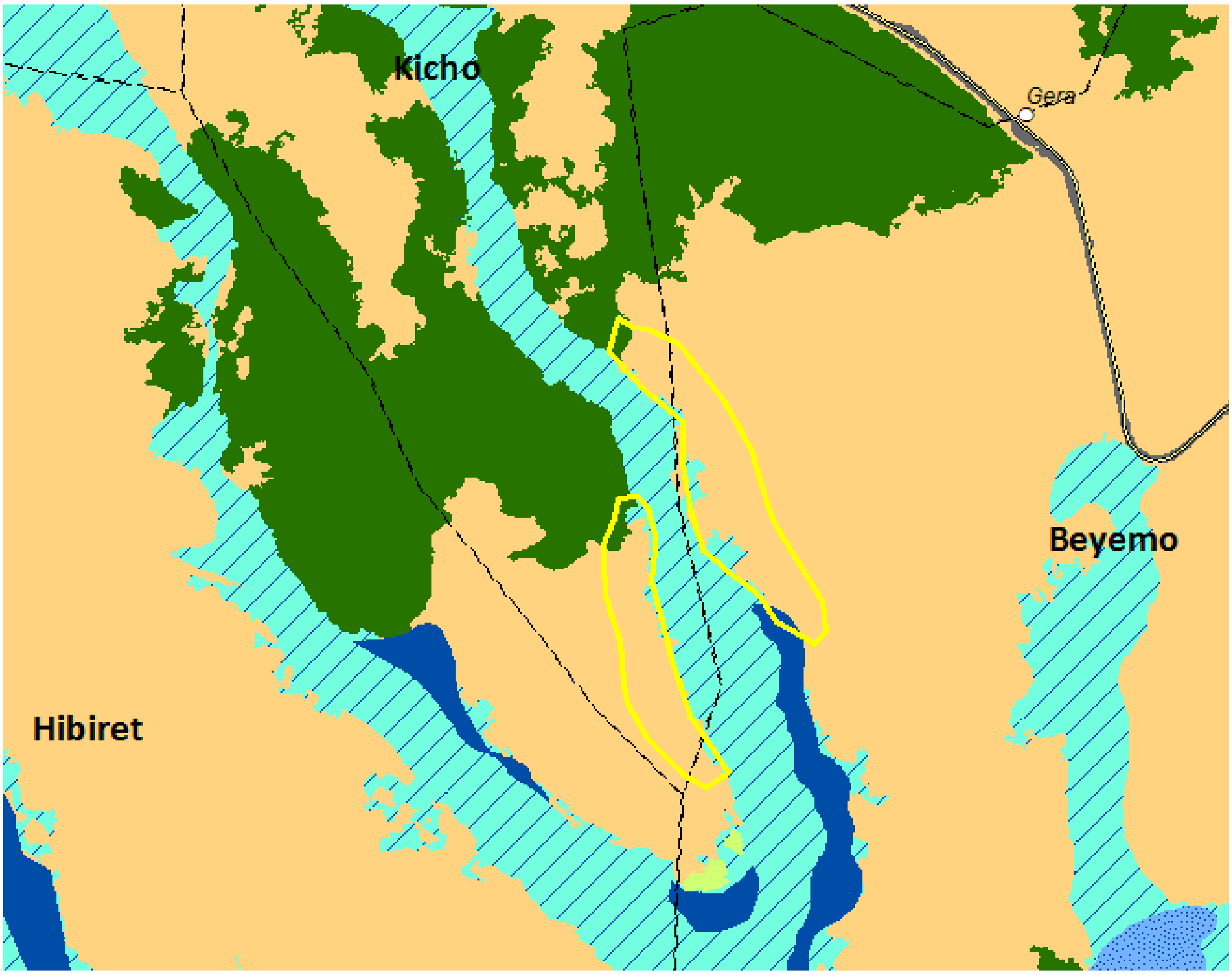


Photo of the location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs framed by agriculture
Present land use	Intense agriculture
Description	Moderately steep slopes - steep slopes | forest converted to agricultural land
Actual threat	Soil erosion, landslide, surface runoff, further encroachment to wetland
Measure	Plant trees as buffer on steep slopes
Size [ha]	11
Kebele	Kicho, Beyemo

3. Buffer Zone of Alemgono

Location: 36°14'44,149"E 7°23'1,202"N | on Vegetation Map (Map 14)

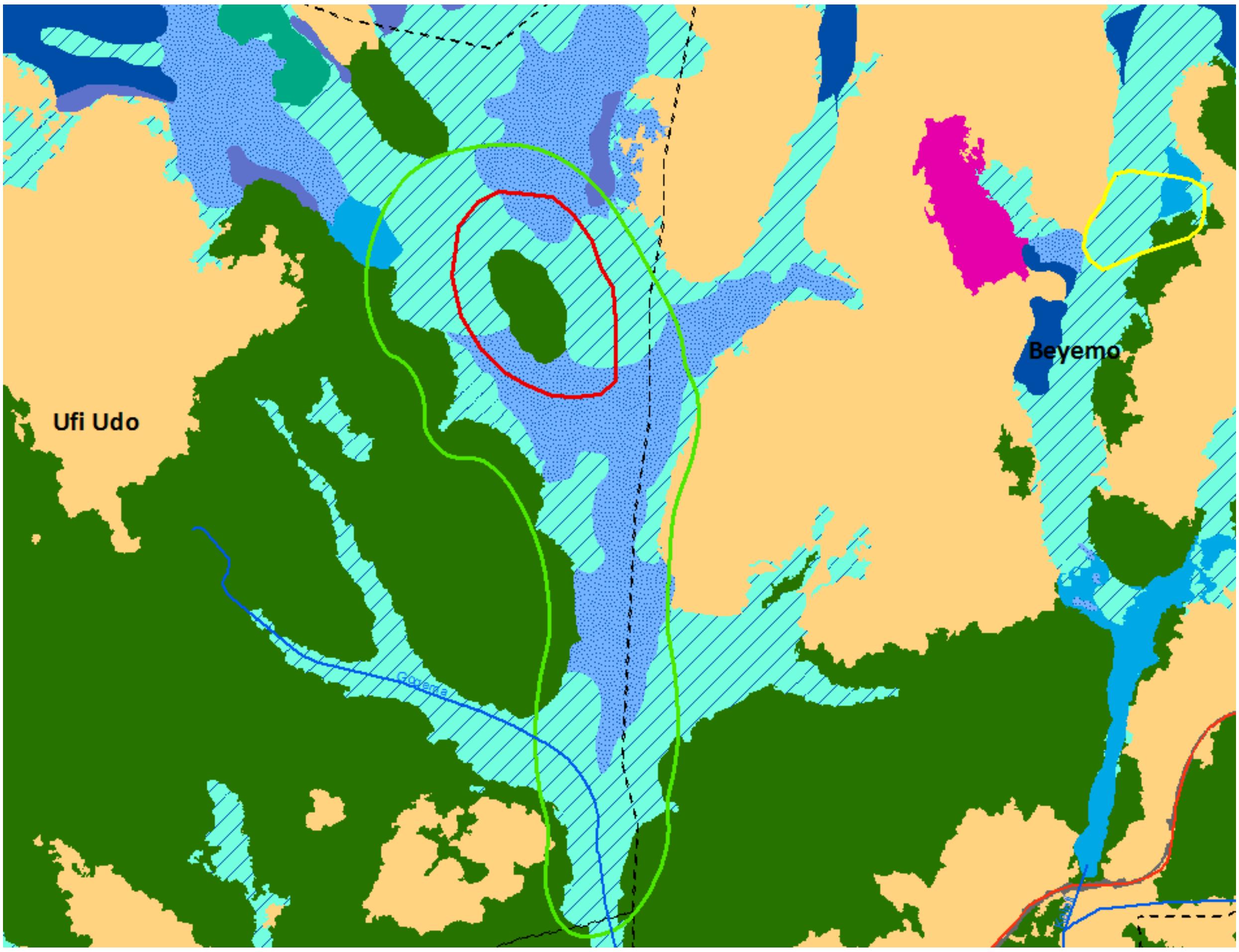


Photo of the location

Present Vegetation	Cyperus latifolius - Schoenoplectus corymbosus forbs | Cyperus latifolius - Ludwigia abyssinica forbs | Hyparrhenia dregeana - Cyperus latifolius forbs | Forest edge
Present land use	Low cattle grazing, cut and carry, collection of construction material
Description	Depression centre with high water accumulation and peat development, landform centripetal
Objective	Buffer core zone, support sustainable use as grazing area, support sustainable use of forest
Measure	Develop sustainable grazing management concept, evaluate if Participatory Forest Management in Chechuwata Forest is possible (next PFM site is 8 km euclidean distance)
Size [ha]	100
Kebele	Kicho, Beyemo

Location: 36°15'28,806"E 7°20'28,607"N | on Vegetation Map (Map 14)

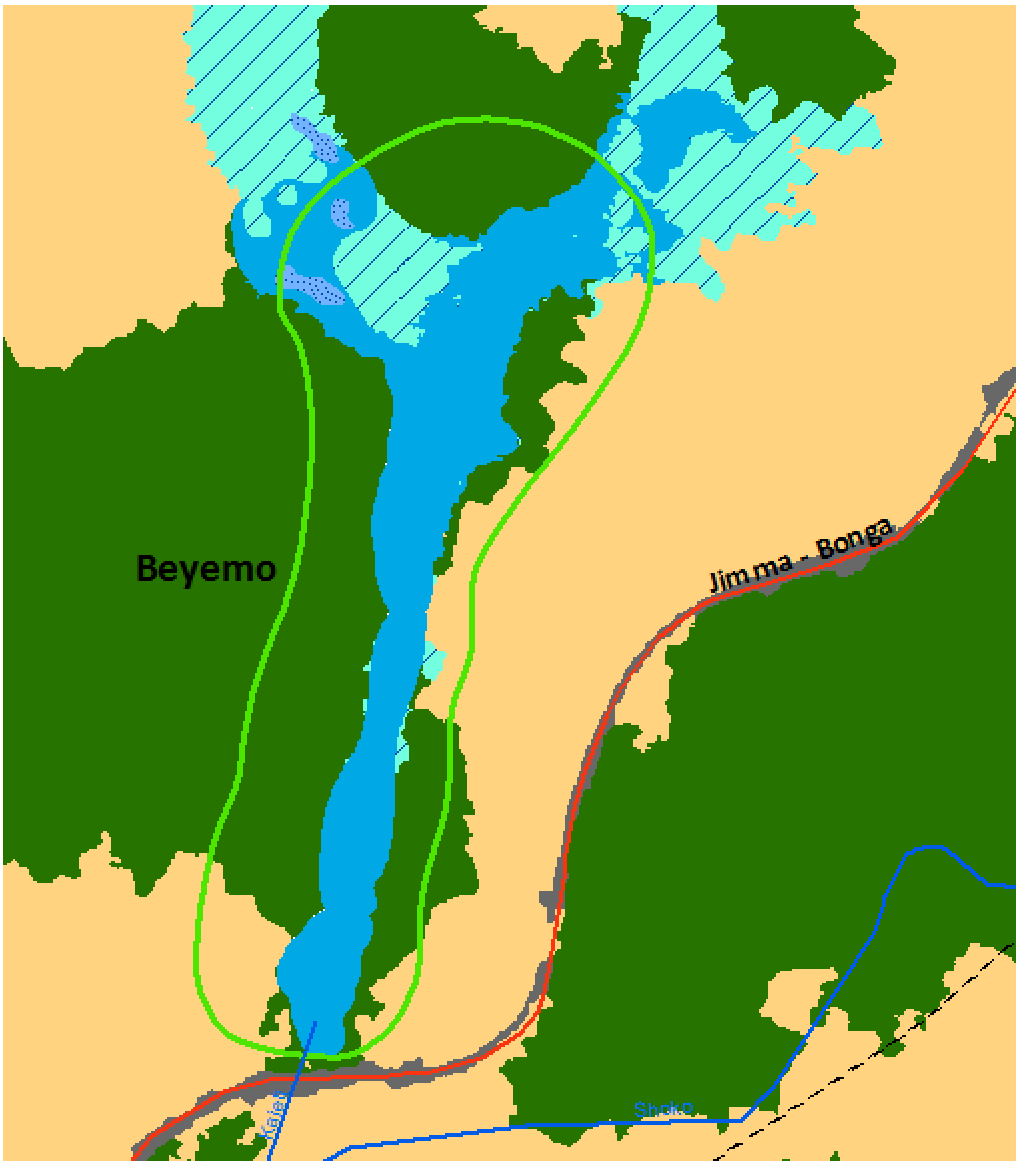


Photo of the location

Present Vegetation	Cyperus latifolius - Floscopa glomerata pasture | Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus latifolius - Schoenoplectus corymbosus forbs | Forest edge
Present land use	Medium-intense cattle grazing, cut and carry, collection of construction material
Description	Channelled outflow espec. in rain season to Kajeti river, moderately steep – steep slopes
Objective	Support sustainable use as grazing area, support sustainable use of forest, source for construction material should be maintained
Measure	Develop sustainable grazing management concept, evaluate if Participatory Forest Management in Chechuwata Forest is possible (next PFM site is 8 km euclidean distance), support NTFPs like honey production
Size [ha]	25
Kebele	Kicho, Beyemo

Location: 36°13'30,128"E 7°22'10,92"N | on Vegetation Map (Map 14)

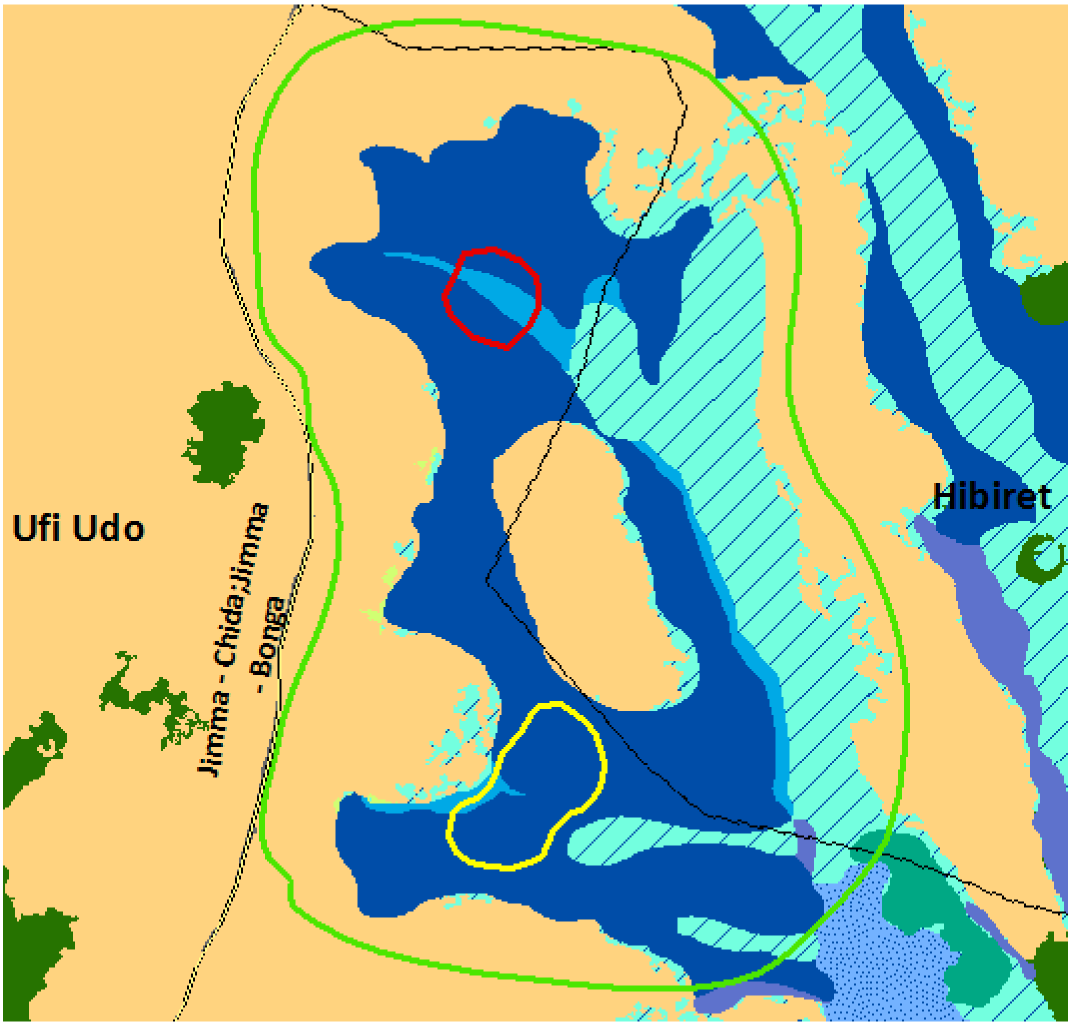


Photo of the location

Present Vegetation	Cyperus latifolius - Floscopa glomerata pasture | Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus latifolius - Schoenoplectus corymbosus forbs | Forest edge
Present land use	Medium-intense cattle grazing, cut and carry, collection of construction material
Description	Channelled outflow espec. in rain season to Kajeti river, moderately steep – steep slopes
Objective	Support sustainable use as grazing area, support sustainable use of forest, source for construction material should be maintained
Measure	Develop sustainable grazing management concept, evaluate if Participatory Forest Management in Chechuwata Forest is possible (next PFM site is 8 km euclidean distance), support NTFPs like honey production
Size [ha]	340
Kebele	Ufi Udo, Hibiret

b. Gojeb

Topographic Maps of EMA does not provide specific names for the floodplains in the morphometric sink around Gojeb, locally known as Gojeb wetland. The montane riverine Gojeb wetland is located around 28 km eastwards from its headwaters, the Ichifa swamp. It is framed by steep slopes, southern slopes are forested, while northern slopes are dominated by agriculture. The settlement Tura is the starting point of the floodplains on the west side, while Boginda town and the passing road mark the endpoint in the east.

The wetland is a typical pass-through system with the lower perennial Gojeb river flowing from west to east. The adjacent floodplains, in the following referred to as “northern part” and “southern part”, are only slightly declined but guarantee a stable water run-off towards the river. Only in some shallow depressions in the north east and very east of the floodplain is water hold long enough for the development of shallow organic soil. The southern part of the wetland is more inclined as the northern part and falls dry earlier after inundations. The northern part is located in a land use matrix of intense agriculture, while the southern part is framed by very steep forested slopes. This setting is rather interesting in terms of estimating the human impact on the wetland, due to the very different intensity of human influence on both sides.

i. Hydrology/ Topography

Gojeb wetland is situated in the same sub-basin as the Omo-Gibe river basin, as is the woredas capital town Konda and is framed by the towns of Daka and Ufa. The sub-basin has a total size of 1,490 km² where Gojeb wetland covers 5% of the area. The altitudinal range of the sub-basin is from 1,323 m.a.s.l. up to 2,950 m.a.s.l. whereas the wetland lies between 1,529 m.a.s.l. and 1,633 m.a.s.l. Compared to other pilot sites (**Fehler! Verweisquelle konnte nicht gefunden werden.**), Gojeb wetland is located on the lowest altitude with the lowest altitudinal rage (115 m). The headwater of river Gojeb is located within this sub-basin but the main contributors are the tributaries accumulating in the Gojeb floodplain (Map 17). Gojeb wetland is a pass-through system located in the centre of the sub-basin and its' hydrologic regime is mainly dominated by the through-flow of river Gojeb. It can be regarded as an ephemeral wetland depending on seasonal and occasional inundations of the Gojeb river crossing the wetland from west to east, dividing the wetland into a northern and southern part. Very characteristic is the meandering river flow of the mature Gojeb river. Tidal variations and flooding have established many oxbows and meander scars, which fill with sediment over time (Figure 40). The different mature oxbows and meander scars are an indication of periodical flooding events.

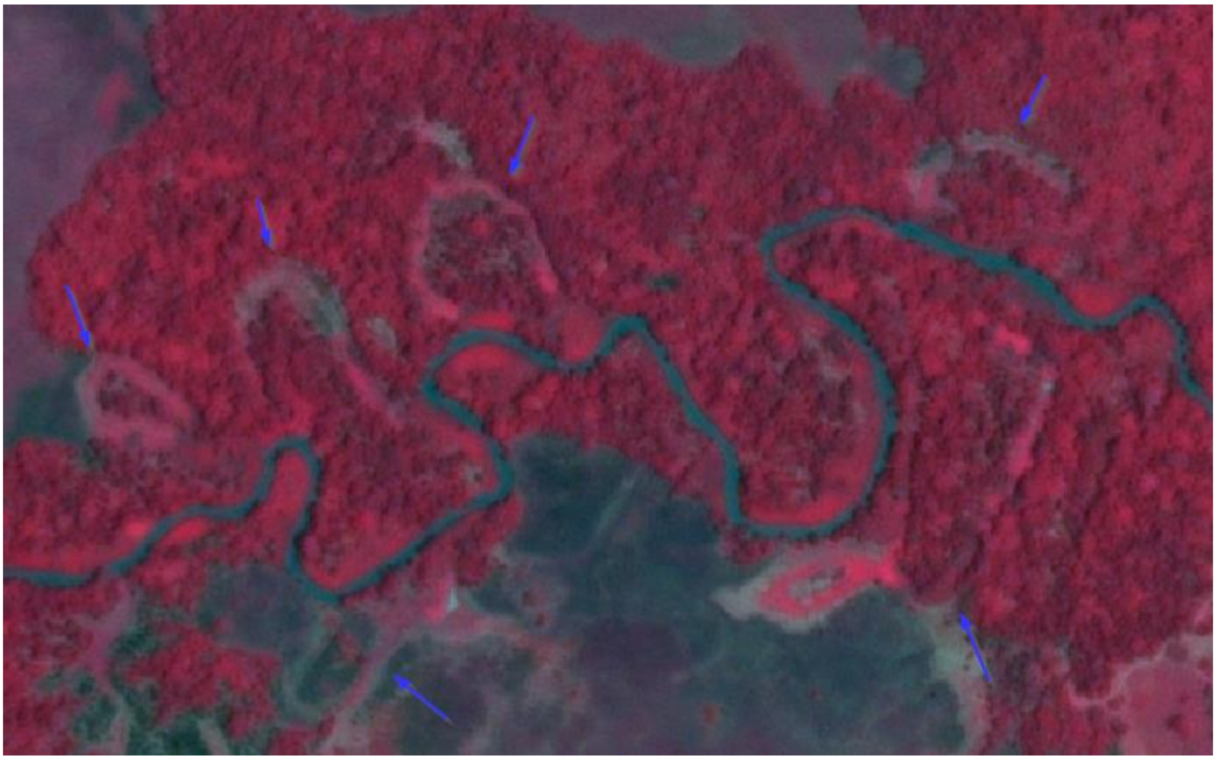
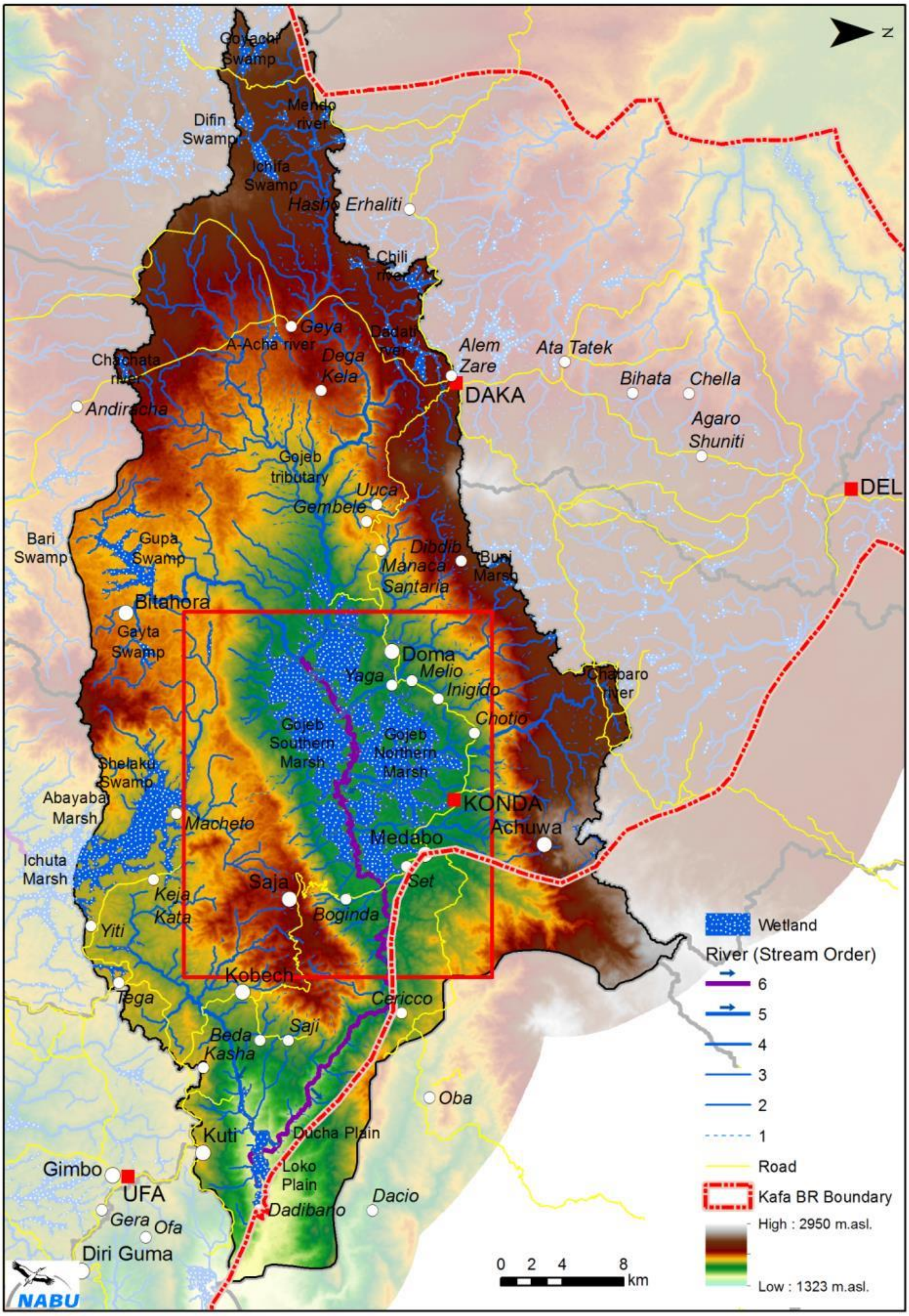


Figure 40: Oxbows from Gojeb river (blue arrows); SPOT5/ false colour composite

Cartographically and in the following, we refer on to the terms "Gojeb Southern Marsh" and "Gojeb Northern Marsh" (Map 17)[25]. Whereas the Gojeb wetland is spatially the most dominant wetland in the sub-basin, there are several smaller ones (Goyachi swamp, Difin swamp, Ichifa swamp, Gupa swamp, Bari swamp, Buni Marsh, Gayta swamp, Shelaku swamp, Abayaba marsh, Ichuta marsh) framing and accumulating in Gojeb wetland.

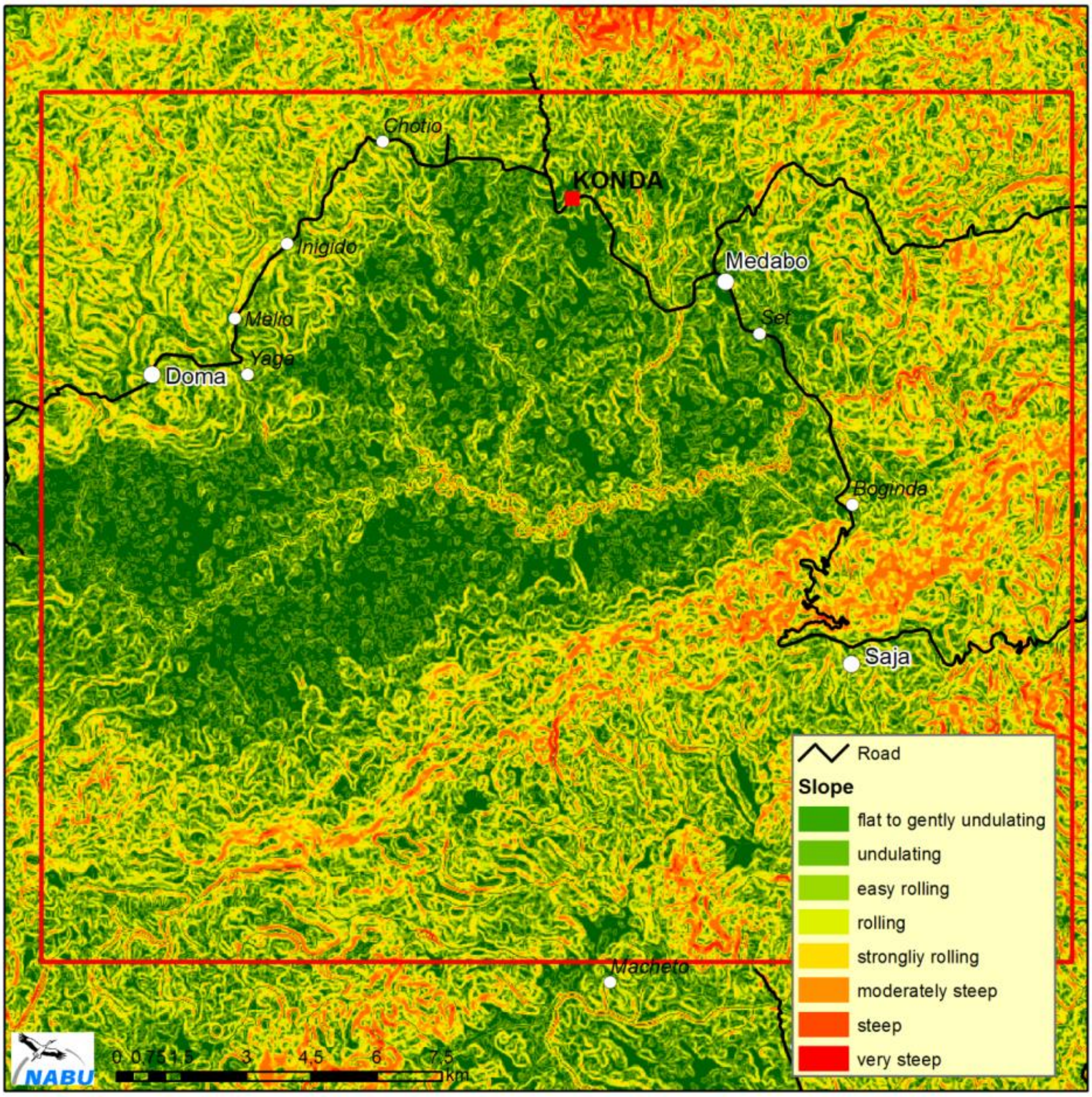
[25] According to Tiner (Tiner 2000), floodplain marshes include wetlands on mineral soils that are periodically inundated by standing or slow-moving water. In contrast to Floodplain swamps, the vegetation is dominated by sedges and reeds instead of being dominated by wood-plants



Map 17: Sub-basin of Gojeb wetland

The Gojeb sub-basin is elongated, following the Gojeb river and shows distributary and dendritic drainage pattern of the tributaries. Outside of the biosphere reserve, Gojeb river confluences with the Omo river. Water accumulates from the upland to low laying areas along Gojeb river. The floodplains are dominated by alluvial processes and have a very small gradient (< 0.01) with a low inclination from west to east. Alluvial transport and deposition of sediment lead to a net accumulation at the natural levees around the meanders of Gojeb river and within the floodplains.

The slope gradient map for Gojeb (Map 18) indicates steep to very steep slopes from the southern upland to the valley bottom. These steep benches are covered by dense mountain forest, forming a natural barrier for high human impact. The northern moderately steep slopes around Konda are covered by intense agriculture and soil stabilization measures are sometimes present (terraces, soil bunds). Water inputs to the floodplains origin mainly from Gojeb river and from adjacent slopes. Only a small proportion of sub-surface water is expected.



Map 18: Slope gradient map for Gojeb wetland (red square identifies the map extract showing Gojeb wetland)

The morphometric character of the Gojeb sub-basin can be found below.

Table 16: Morphometric Character of the Gojeb sub-basin

Order of Stream	Number of Streams	Bifurcation Ratio	Total Stream length [km]	%	Average Stream length [km]	Length Ratio
I	1164		1109,43922	48,7532832	0,953126	
II	271	4,30	589,237341	25,8934916	2,174308	2,28
III	72	3,76	278,254524	12,2276385	3,864646	1,78
IV	17	4,24	147,453279	6,47969837	8,673722	2,24

V	4	4,25	84,588421	3,71716016	21,147105	2,44
VI	3	1,33	66,646711	2,92872825	22,21557	1,05
Σ	1531		2275,61949			
Ø		3,6	1,4			1,96

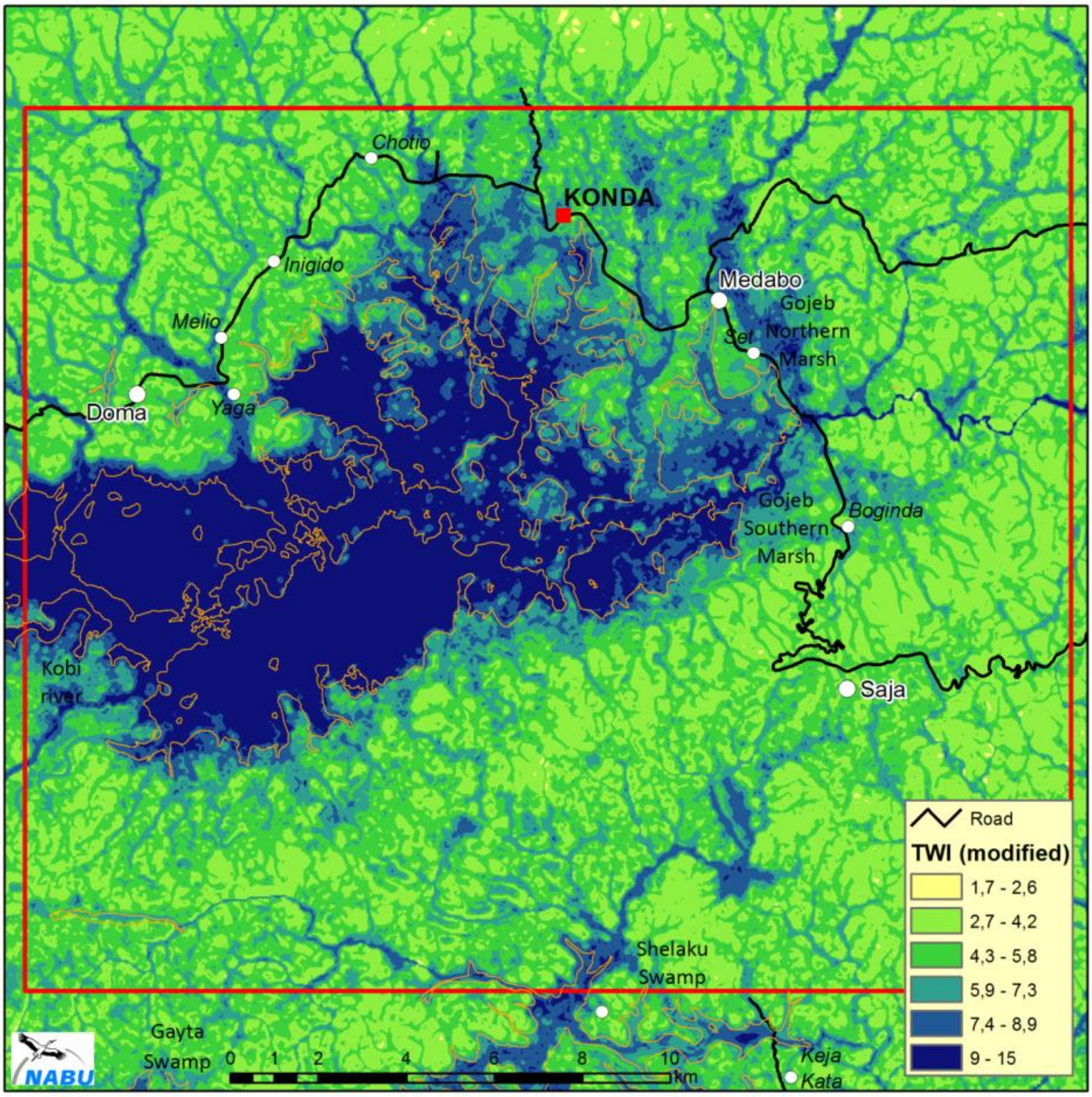
The morphometric parameters of Gojeb sub-basin are statistically not significantly different from the overall estimation of the Kafa BR (Table 2). But the mean river length ratio show a smaller range than for the whole Kafa BR but higher range than for the other pilot sites (**Fehler! Verweisquelle konnte nicht gefunden werden.**). This underpins a distinct topography between the lowland plain and steep mountain slopes. Accordingly, different habitats are present at the distinct altitudinal gradient.

The drainage density is comparable with the other pilot sites (1.5 km/km²).

The headwater is located in the west of Gojeb wetland, named Ichifa swamp. The upper course of Gojeb flows more or less straight over a steep gradient with erosive character and leaving a steep-sided valley before entering the Gojeb wetland. Accordingly, sediment transport and nutrient enrichment to the middle and especially lower course is high. Due to a moderate gradient in the middle course, the vertical erosion energy is less and an increase in width and flow volume can be observed. Entering the floodplain, Gojeb river has a width of 20 – 22 m and according to the Topo map (0736C2/ETH4; 2001) a flow velocity of 0.6 m/sec.. In the lower course, the floodplain widens and Gojeb river confluence with Geni river(order class 5). According to Strahlers' steam order Gojeb is becoming a stream of 6th order. The minimal gradient make the down cutting of the relief impossible, hence no slopes can occur in the lower course. Referring to the gradient map (Map 18) some limitations of the modelled depressionless DTM become obvious. At the eastern part of the lower course in the floodplain, some narrow steep slopes along Gojeb river occur. This effect is actually not realistic but could not be avoided. The very low gradient of the floodplain had virtually to be exaggerated to simulate the correct flow direction, which leads to a visible "burned in" stream network. Accordingly, this effect leads to a slight overestimation of the average slope gradient with 8.3° for Gojeb wetland. This is, compared with Alemgono (13.7°) and Chid (46.2°) still very low average slope gradient and stretches over a long longitudinal distance of 19 km. The total length of Gojeb river is two times higher than the Euclidean distance. It accounts for 40 km due to meanders within the floodplain. The minimal gradient in the lower course and the sediment deposition provides the environment for a meandering stream. Meander cut-offs occur especially during floods(Gabler et al. 2009). The cut-offs fill with water and leave a so called oxbow, which will fill with deposited sediments and become a meander scar. All stages from oxbow till meander scar can be found along Gojeb river (Figure 40) and indicate periodical flooding events. The adjacent forest buffer of the Gojeb wetland can be seen as temporarily waterlogged. This assumption should be verified by further field visits.

Different tributaries with stream order higher than three enter the Gojeb river in the lower course, namely Chorora, Halary, Soto, Sotiyo, and Boginda. All major tributaries are found in the northern floodplain. One reason for this might be the bigger upslope contributing area of the northern floodplain, but also a different hydrodynamic. While the southern floodplain is dominated by vertical fluctuation, the northern floodplain show a unidirectional flow. At the southern mountain slopes, different springs are reported during the in-depth interviews.

The Topographic Wetness Index indicates that both, northern and southern floodplains are well saturated with water with different outcrops especially in the northern part (Map 19). The moisture content is highest at the middle course at the west side of the floodplains. This was also found during field visits and might be the result of altering lithology and sediment deposits from upstream areas. The major influence of tributaries on the northern side cause a more widen floodplain up to 6 km[26], while the southern floodplain shows a maximum width of 3.5 km.



Map 19: Topographic Wetness Index (modified) for Gojeb wetland (red square identifies the map extract showing Gojeb wetland)

[26] The river Soto has the biggest impact of widening the northern floodplain and stretches from Konda to Gojeb river.

The floodplains of Gojeb wetland stretch from the middle course to the lower course of Gojeb river and is covering a complex of different hydrogeomorphic features. Inherent to all parts is the genesis through alluvial processes of Gojeb river. Furthermore, several parts of the floodplains are flooded on a regular basis during distinct peak flow events, e.g. during the mid of rainy season (August). The active channel of Gojeb, naturally free of terrestrial vegetation (Ollis D, Snaddon K, Job N 2013), is believed to be covered wetland and pioneer vegetation. This assumption is based on satellite image interpretation but could not be crossed checked in the field. Adjacent to the active channel is the well drained riparian forest, which actually does not have typical wetland characteristics. Hence, it is not classified as wetland. Here, further research is needed, whether this part is saturated or flooded for prolonged periods so that it would be considered as wetland as well.

Dominant water sources of the northern floodplain are overbank flow from Gojeb river, tributary inflow and surface runoff into the wetland. Groundwater inflow is also expected but should be confirmed by water chemistry analysis. The southern floodplain is mainly fed by overbank flow, surface runoff into the floodplain and groundwater discharge. The reasons for the different water sources are probably due to different composition of lithology and surface vegetation. A minor west-east unidirectional flow is assumed. The in-depth interviews show, that a seasonal vertical fluctuation might exist. They also mentioned a higher water table in the past (northern floodplain) which can have different sources. A differentiation of the hydrodynamic of both floodplains cannot be drawn out of the interviews.

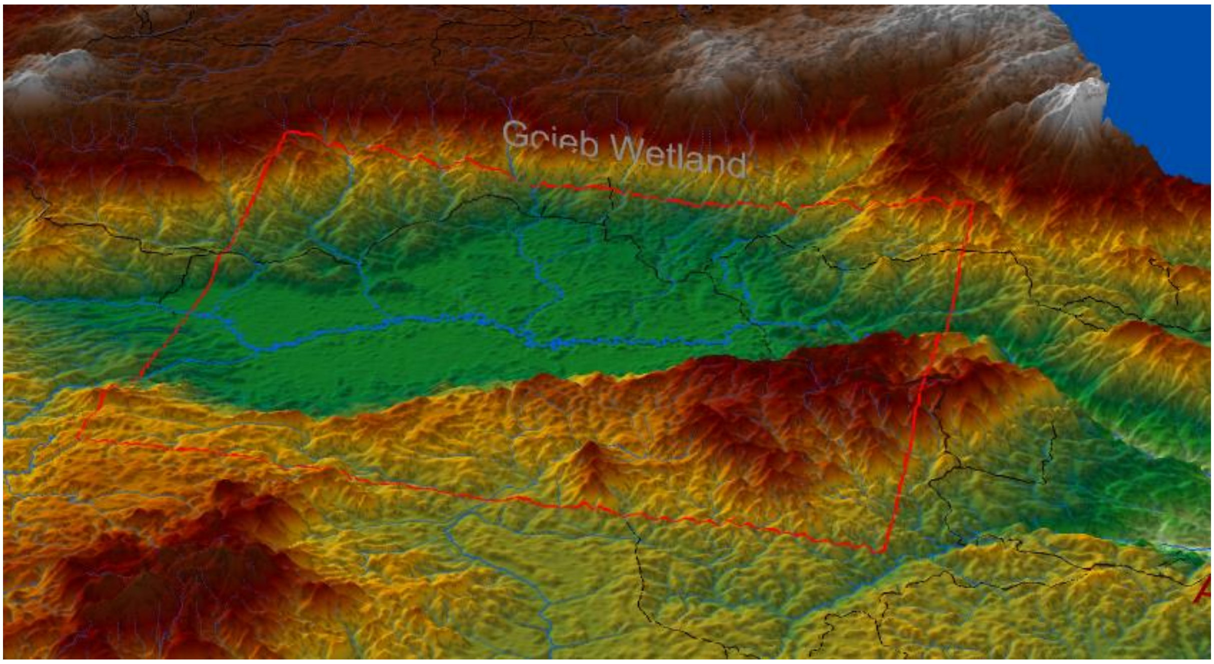


Figure 41: 3D view of Gojeb wetland (vertical exaggeration x3) with modelled river network (blue) and main roads (black)

Size and position in the landscape (Figure 41) of Gojebs' floodplains support a variety of features, such as meander cut-offs, backwater depressions, alluvial ridges etc. This complex landscape has different wetland dynamics inherent. Some parts might be dominated by waterlogging others might be less affected by floods. Anyhow, to understand Gojeb wetland as a whole it can be classified as low-gradient alluvial floodplain depression with a channelized flow through with overbank flooding, which is together with groundwater inflow and lateral surface flow the main water source. Naturally, it is a through-flow system but the floodplains serve as flood storage and conserve groundwater discharge. Generally, low gradient floodplains are known to be major fish and wildlife habitats with high biodiversity (M.M. Brinson 1993).

ii. Vegetation

In Gojeb Wetland we find mainly vegetation classes adapted to mineral soils like Arundo donax - Melanthera scandens forbs and Cyperus latifolius - Vigna pakeri pastures (see Map 6). Hyparrhenia dregeana - Cyperus latifolius forbs which were observed on organic soils in Alemgono Wetland do occur on mineral soils in considerable stands in the northern and southern part. Arundo donax-Melanthera scandens forbs and Hyparrhenia dregeana - Cyperus latifolius forbs south of Gojeb river are not visibly influenced by grazing and can be regarded as natural vegetation units of the floodplains. In contrast to the former mentioned, the Cyperus latifolius-Vigna pakeri pastures north of Gojeb River do only develop under the constant influence of grazing cattle.

In the eastern wetland, south of Gojeb River, waterlogged meadows were found, that were, due to the inaccessibility for cattle, obviously grazed by natural grazers. The local guides reported about the presence of African Buffalo and Hippopotamus, as well as African Lion and Leopard.

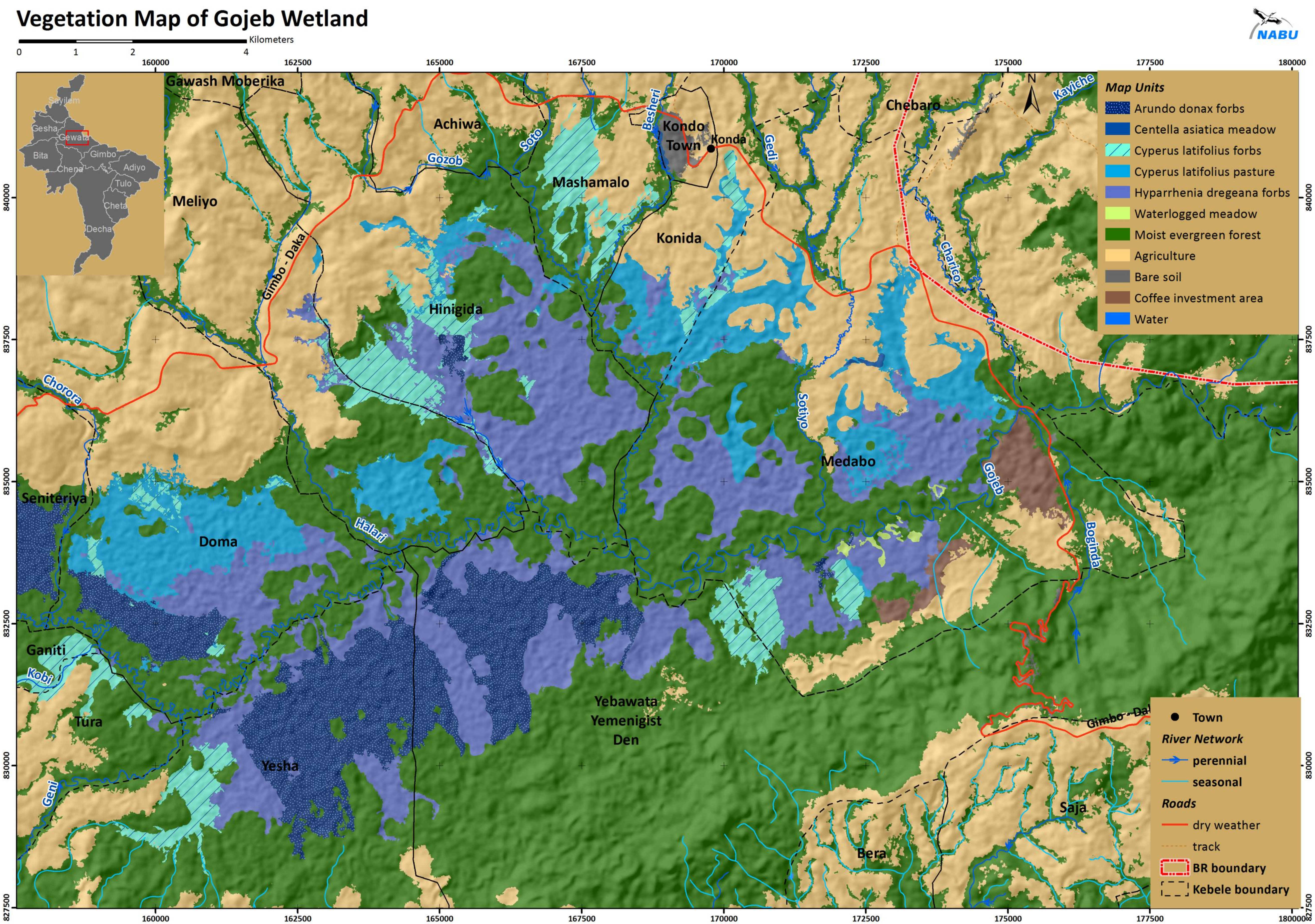
Table 17: Vegetation & Map Unit for Gojeb pilot site

Vegetation unit	Map unit	Area in ha
***Arundo donax - Melanthera scandens* forbs**	Arundo donax forbs	1612,85
***Centella asiatica* meadow**	Centella asiatica meadow	13,44
***Cyperus latifolius - Ludwigia abyssinica* forbs**	Cyperus latifolius forbs	963,56
***Cyperus latifolius - Vigna pakeri* pasture**	Cyperus latifolius pasture	1551,97
***Hyparrhenia dregeana - Cyperus latifolius* forbs**	Hyparrhenia dregeana forbs	2935,63

Table 18: Species list and site description for Gojeb pilot site

	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Hygrophila schulli	Acanthaceae	moist depessions,marshy places					
Berula erecta	Apiaceae	mashy area	x			shallow water	
Centella asiatica	Apiaceae	damp grassland, swamp		x	x		
Gomphocarpus semilunatus	Apocynaceae	alluvial grassland		?	x	seasonally flooded	
Melanthera scandens	Asteraceae	swamp margins, river banks	x		?		

	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Floscopa glomerata	Commeliaceae	damp meadows, ditches, boggy grassland		x	x		grazing weed
Cyperus latifolius	Cyperaceae	swamp	x			wet ground	raw material, roof thatching
Phyllanthus boehmii	Euphorbiaceae	marshes, swampy grassland, wet banks	x				
Vigna pakeri	Fabaceae	grassland, woodland, forest margins, cultivations		x	x		
Urticularia stellaris	Lentibulariaceae	damp, shallow soil				submerged	
Dissotis cf. decumbens	Melastomataceae	stream margin in riverine forest					
Ludwigia abyssinica	Onagraceae	swampy ground, near rivers lakes	x				
Hyparrhenia dregeana	Poaceae	seasonally damp depressions, open grassland stony hillsides				seasonally moist/wet	grazing ?
Arundo donax	Poaceae	open wet soils by rivers, ditches				seasonally moist/wet	raw material, shelter, handicraft, grazing
Persicaria strigosa	Polygonaceae	marshy ground,swamps, lake shores, wet grassland					
Persicaria setosula	Polygonaceae	damp places				sometimes in water	
Crepidorhopalon whytei	Scrophulariaceae	montane swamps	x				
Thelypteris confluens	Thelypteridaceae	swamps, floating bogs?	x			wet	peat formation
Triumfetta rhomboidea	Tiliaceae	paths in forests, degraded bushland			x		



Map 20: Vegetation Map of Gojeb Wetland

iii. Soil

Floodwater dynamics, overbank flooding and subsequent floodplain deposition, and erosion from surface flow patterns, along with remnant meander scars and levees, produce distinct surface topographic and soil variations. Gojeb Wetland mainly consists of river floodplains with mineral soils which are built of alluvial substrates of the rivers sediment load. The floodwater of Gojeb river carry sediments and debris and supports nutrient retention.

The dominate soil type is gley. At some sites prolonged inundation causes waterlogging with accompanying influences on soil genesis. In the north east and east of the wetland in very even and flat parts of the floodplain areas with organic soils are expected as in the very east of the wetland paludification and initial peat soils have been observed (FT26).

iv. Hemeroby/ Threats

The northern and southern floodplains are very different concerning the human intervention. Consequently, both floodplains different degrees of Hemeroby are assigned.

The southern floodplain is naturally bordered and protected of human activity by very steep forested slopes. The southern floodplain is difficult to access and settlements are rare and scattered. It is in wide parts ahemerob to oligohemerob.

The northern floodplain can be described as mesohemerob to polyhemerob due to year around intensive grazing of cattle. The grazing pressure decreases towards the Gojeb river with the increasing distance to settlements. The Gojeb river is framed by a nearly undisturbed riparian forest. It was found, that go boating is not common in the area, which makes wide parts of the riparian forest inaccessible.

Figure 42: Diverse riparian forest along Gojeb river (photo by F. Mundt)

Correspondingly to the differentiation of the floodplains concerning the degree of hemeroby, threats of both floodplains are also different in nature. Anyhow, during interviews on both sides, the main underlying reason for mentioned threats to the natural vegetation of the floodplain was identified with the insecure land tenure. Land tenure insecurity is generally knowen to be a major factor that affects sustainable investment in Ethipia (Josephson et al. 2014) and furthermore the main concern to initiate the very successful concept of Participatory Forest Management (Brown n.d.).

The northern floodplain is heavily influenced by human activities and suffers partly under heavy overgrazing (Map 21). As visible in Map 27: Tropical Livestock Unit per hectare in Kafa BR, the northern floodplain is exposed to very high TLUs. Areas not prone to inundation are heavily grazed. Only little pristine nature has been left. Cattle do not only exterminate the natural vegetation, the heavy animals induce soil compacting, erosion and the loss of ground covering vegetation.

Figure 43: Overgrazing in Gojeb Wetland (photo by C. Tegetmeyer)

The use of huge amounts of fertilizers on the adjacent farming land might lead to eutrophication, salinization and hence the loss of biodiversity and habitat fragmentation. Considering the main water sources of the northern wetland, accumulation of fertilizer and other pollutants is very likely! The northern floodplain accumulates all material below the watershed divide from Chabaro River at north-eastern edge up to the town Daka. As the northern floodplain is framed by Kebels with high population density (> 200 p/km²; Map 29) and the accessibility is very good (Map 28) it is believed that the pressure on ecosystem services will even increase in a mid-term. It can be clearly observed that accessibility promotes an increased use of ecosystem services in some sites beyond the capacity of the ecosystem.

The southern floodplain itself faces minor threats through human interventions. At the eastern edge of the floodplain, close to Boginda town, two coffee investment areas (approx. 200 ha) stretches towards the wetland. A field visit proved an intense management, with a completely cleared undercover. As the southern floodplain does not bear so many conflict potential with local communities (low population density), and the presetting landcover is ideal for the development of ICAs, it is worth a mention as a potential threat. The application of agrochemicals at existing ICAs seems to be most likely.

A direct threat for the southern floodplain was already detected during a field visit in 2008. According to a satellite time series and visual change detection comparison, the deforestation trend is continuous. Settlers were found to practice slash and burn practices within the mountainous forest adjacent to Hyparrhenia dregeana -Cyperus latifolius peatland (Figure 44; Map 21). Personal communication with the villagers, proved a resettlement enforcement in 1987 in the Boginda region. According to their depiction, all forest dwellers (in this place around 45 households) had to leave the forested area in 1987. The enforcement was rigorous by burning their fields. They were urged to resettle in near-by villages outside the forest. The trend to return seems to continue, with the consequence of creating access to remote areas and clearing sites adjacent to the floodplain with all resulting impacts from deforestation named under Figure 23 (page 47). The forested slopes fulfil various important functions, contributing to the natural state of the wetland.

Detection of deforestation (marked with red ellipsoids) on SPOT5 (2011) close to Hyparrhenia dregeana -Cyperus latifolius peatland	Slash and burn for recultivation (Photo: E. Dresen 2008 | 36°0'13.995''E 7°30'36.76''N)

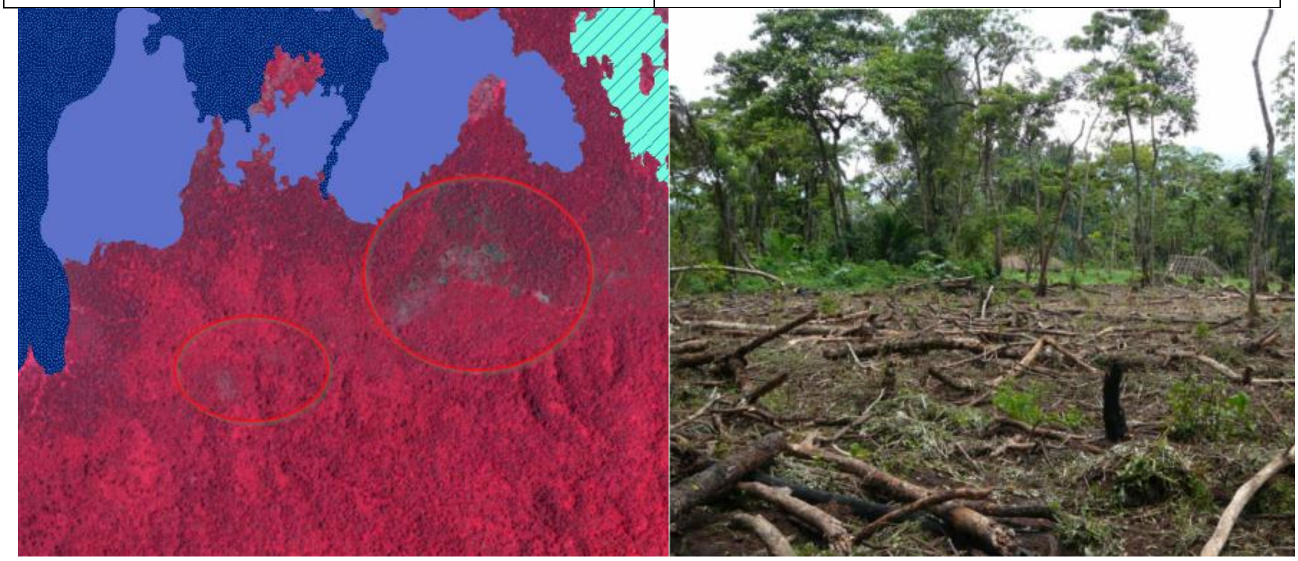
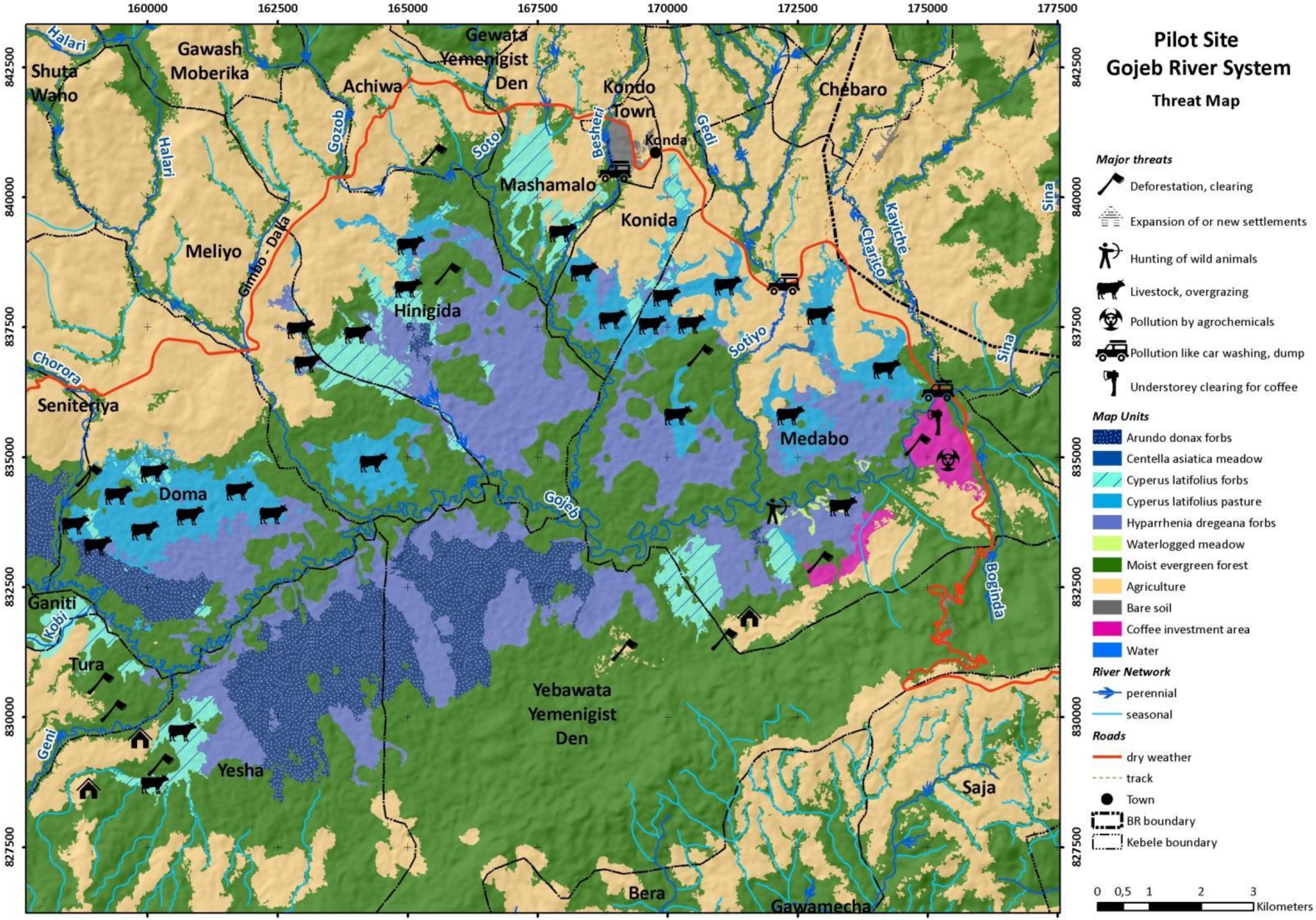


Figure 44: Deforestation adjacent to the southern floodplain of Gojeb wetland



Map 21: Threat Map, Gojeb River System

v. Management/ Monitoring

As the degree of hemeroby and the direct threats to both floodplains differ, the proposed management has to be adapted to both floodplains.

Southern floodplain:

The management strategy for the southern floodplain should seize the actual state of a nature-accentuated area and protect large connected, heterogeneous habitats as retreat area for endemic and threatened species. According to the actual weak human impact and a low population density (< 80 p/km²; Map 29), the potential for conflicts between environmental protection and development is low.

The still pristine southern floodplain is one of the last, spatially significant more or less natural and undisturbed ecosystems of the Kafa biosphere reserve. To keep the wetland in the current stage to guarantee the future existence of retreat habitats for the natural flora and fauna, it is mandatory to prevent further settlement (and slash and burn) in the adjacent mountain forest. Although the flora survey showed relatively high species diversity largely due to subtle differences in soil moisture resulting from upslope variations in the soil profile and water table regime, no rare or internationally important species were identified.

The riparian forest along the Gojeb river, believed to be the Potentially Natural Vegetation (PNV), should be protected against human intervention. Due to active hydrodynamic, there is a continuum of younger and older features associated with channel migration which leads to various “micro-habitats” and a high diversity. The local community depicted from regular occurrence of Hippopotamus (Hippopotamus amphibius), African Lion (Panthera leo), Leopard (Panthera pardus), African Buffalo (Syncerus caffer) and African Wild Dog (Lycaon pictus). To maintain retreat areas for protected and threatened species of national and international interest, it is highly recommended not to intervene in the natural changing environment along the Gojeb river. During the field visit, some hunters (carrying weapons) were observed. To which extent and on which species hunting is practiced cannot be reported and further research should be conducted.

Currently, the southern wetland provides physical benefits to very few people. Only about 15 households settled in the Boginda forest, adjacent to the wetland directly benefitting from the floodplains’ ecosystem services. At the upper course where Geni river joins Gojeb river, a few local people benefit from cattle grazing in the floodplain. The same situation can be found at the eastern lower course (from Boginda town following Gojeb river 4 km upstream) where the local community is also involved in cultivation. A very interesting finding from in-depth interviews is the major importance of medical plants (6.9% of interviewees named this as most important ecosystem service, whereas in other pilot sites this was not even mentioned). This extensive activity would be in harmony with the environmental protection concept.

Northern floodplain:

The flora survey, including remote sensing analysis, found that the vegetation structure and composition within the northern floodplain, have been influenced by past and present management practices, primarily by cattle grazing. Cattle are stocked at about 3 -4 cows per hectare[27], assuming the Kebeles Medabo, Qonda, Mesha Mello, Hinigido, Maliyo and Duma practice full wetland grazing. Besides the impact on plant diversity, there is evidence of erosion along the tributaries of Gojeb, which are often used as cattle path. Some parts are more intensely grazed than others. It is believed that the seasonal inundation prevents parts of the northern floodplain from being grazed during the main growing season. Thus the length of the dry season determines the length of the period of grazing. This effects the species composition, structure, and productivity, but could also be understood as a time for natural regeneration. Cyperus latifolius pasture is dominating the adjacent agriculture land.

In-depth interviews revealed that the most important ecosystem service for local communities is construction material (96.3%) and grazing (3.7%). At present, the floodplain provides very important benefits for a dense populated area in an agricultural matrix with very high TLUs. Whereas the service of providing construction material seems not to be overexploited (vast areas with dense Cyperus latifolius occur), the grazing intensity causes a major impact on the PNV and on physical soil properties[28]. Cultivation within the wetland is not present, but there are activities recognized which indicate an illegal encroachment towards the wetland (by clearing the forest belt at the wetland borders). All interviewed farmers identified the insecure land tenure as the major threat for the ecosystem and a sustainable management.

As the northern wetland is extensively modified from its' PNV, there are three possible management strategies. Efforts could be made to either restore the ecological condition towards more "naturalness" , or taking into concern the high contribution to social welfare, the wetland could be assigned as "working wetland"(Williams et al. n.d.) where development is more important than nature conservation. The middle road we suggested appears to be a good compromise between the trade-off of environmental protection and development.

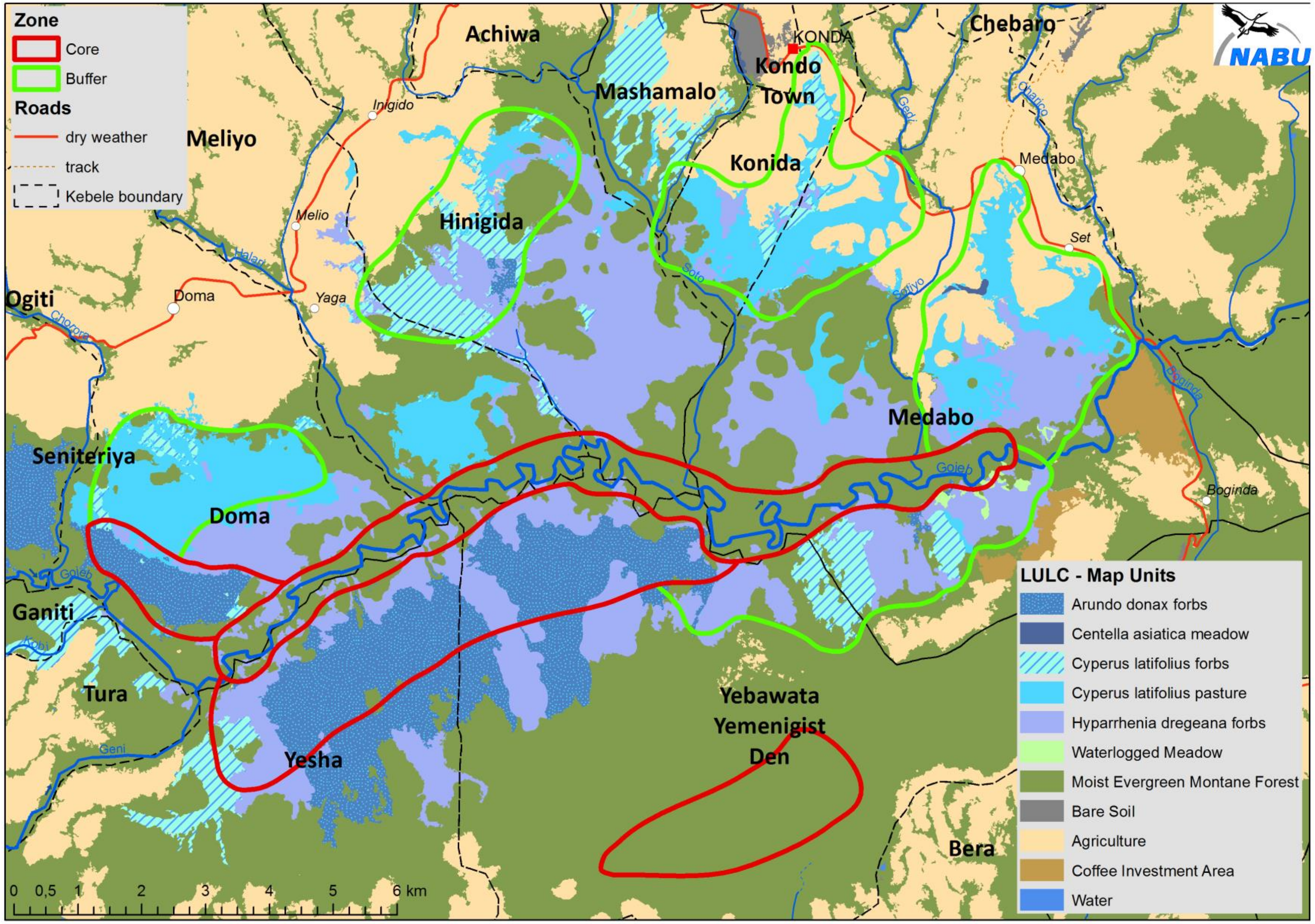
The northern floodplain is classified as a groundwater discharge area, which results in more nutrient content water than wetlands mainly fed from rainwater. Consequently, plant communities that receive groundwater discharge tend to be more productive than e.g. organic soil flats(M.M. Brinson 1993). The diverse water sources of the floodplain offer permanent water. This biophysical setting seems to be appropriate for a good pastoral management, probably with a similar ownership – responsibility model like existing for forested areas, where local communities take responsibility with a purchase of shares on forest resources. Participatory Forest Management (PFM) is very positively affiliated from communities and different studies in the Kafa BR provide evidence for a successful enforcement. The fairly good access to markets and the defined shortage of land depicted in interviews could also be a reason for releasing a certain amount of the floodplain for sustainable small-scale agriculture. To provide social welfare to a maximum of stakeholders it is suggested to hamper all large scale irrigation projects.

According to collated and evaluated information, a proposal of zonation – open for discussion – will be showen below. It should be understood as a baseline for a participatory process with all stakeholders and improved by further research. A spatialization was not possible in all cases due to missing ground

[27] Wetland vegetation in the northern floodplain for Kebeles Medabo, Qonda, Mesha Mello, Hinigido, Maliyo and Duma approx.. 4,274 ha | Total cattle stock of Kebeles Medabo, Qonda, Mesha Mello, Hinigido, Maliyo and Duma approx. 15,830, according to MoARD (2015) → overestimation possible, due to the assumption of pure wetland grazing

[28] Further research should be done to estimate the impact on the chemical soil properties which might indicate a non-reversible change of wetland soil properties.

truths of the specific sites. Photo documentary was not available for all proposed sites, (all photos are taken during the 1st, 2nd, 3rd field visit, mid – end of dry season). The legend of the zonation overview will be valid for the detail extracts.



Map 22: Proposed Zonation of Gojeb Wetland

1. *Core Zones of Gojeb*

SF = Southern Floodplain

NF = Northern Floodplain

Location: 35°58'42"E 7°32'14,21"N | on Vegetation Map (Map 20)

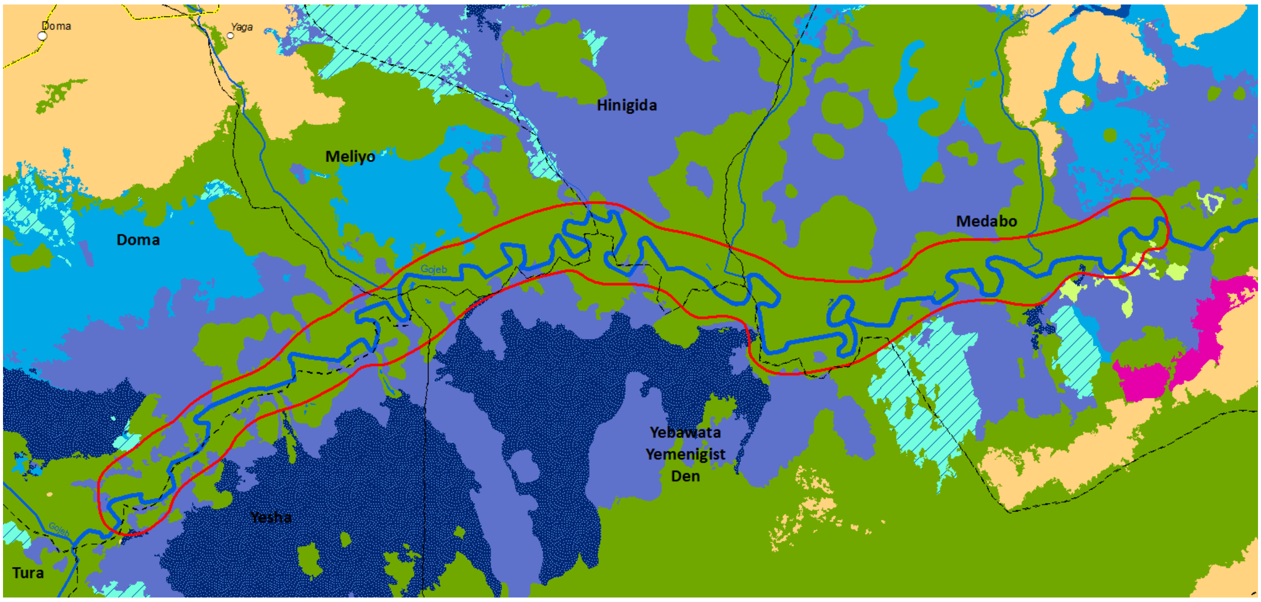


Photo of location

Present Vegetation	Riparian forest | Hyparrhenia dregeana - Cyperus latifolius forbs
Present land use	At some parts selective cutting
Description	Protection of dynamic river course with high biodiversity
Function/ objective	Habitat of keystone species
Size [ha]	1060
Kebele	Northern Floodplain: Doma, Hindigida, Medabo, Southern Floodplain: Yemenigis Den, Yesha

Location: 35°57'45,35"E 7°31'6,761"N | on Vegetation Map (Map 20)

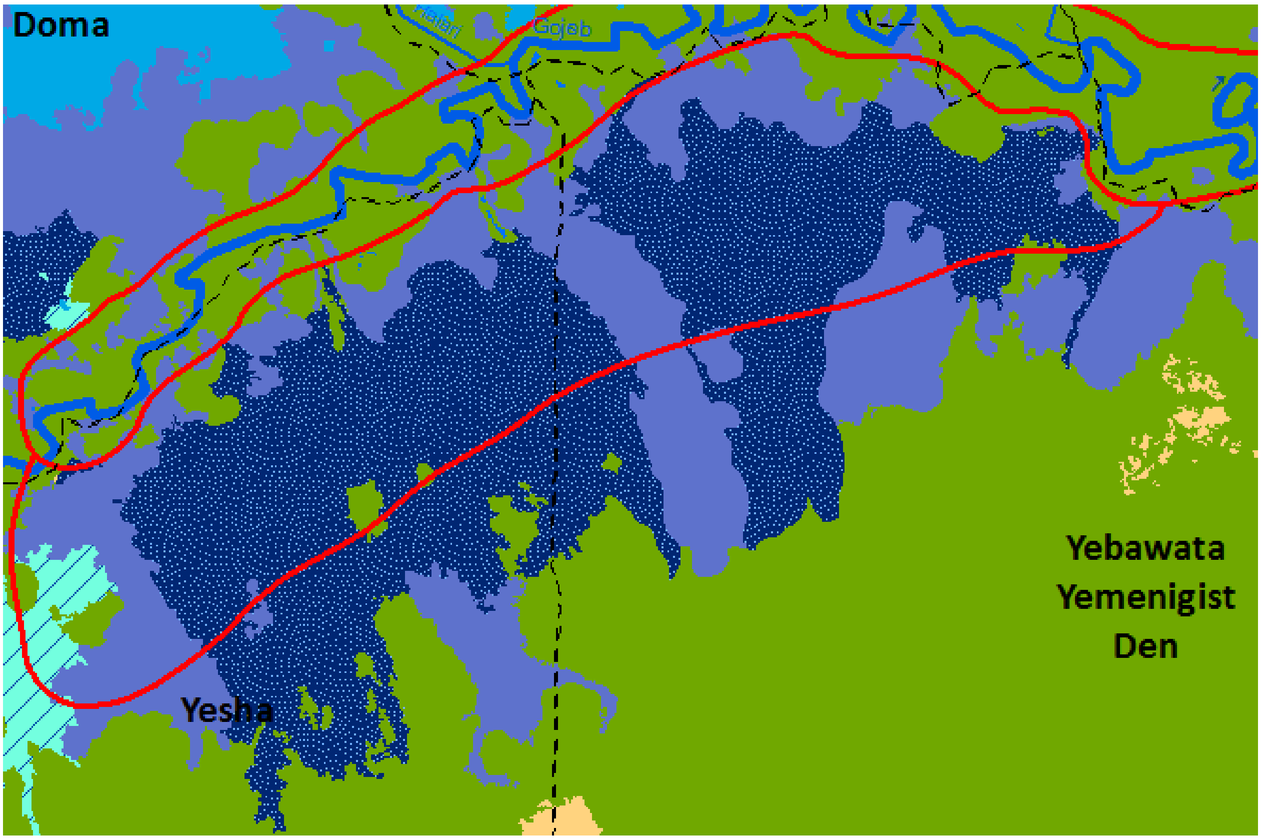


Photo of location

Present Vegetation	Arundo donax - Melanthera scandens forbs | Hyparrhenia dregeana - Cyperus latifolius forbs | Cyperus latifolius - Ludwigia abyssinica forbs
Present land use	In dry season probably cutting of Cyperus latifolius (not confirmed)
Description	Vast wetland area with very low or without human intervention, already classified as Candidate Core area of Kafa BR
Function/ objective	Pristine connected area as retreated area for wildlife
Size [ha]	1,300
Kebele	Southern Floodplain: Yesha, Yemenigist Den

Location: 36°0'11,251"E 7°29'11,07"N | on Vegetation Map (Map 20)

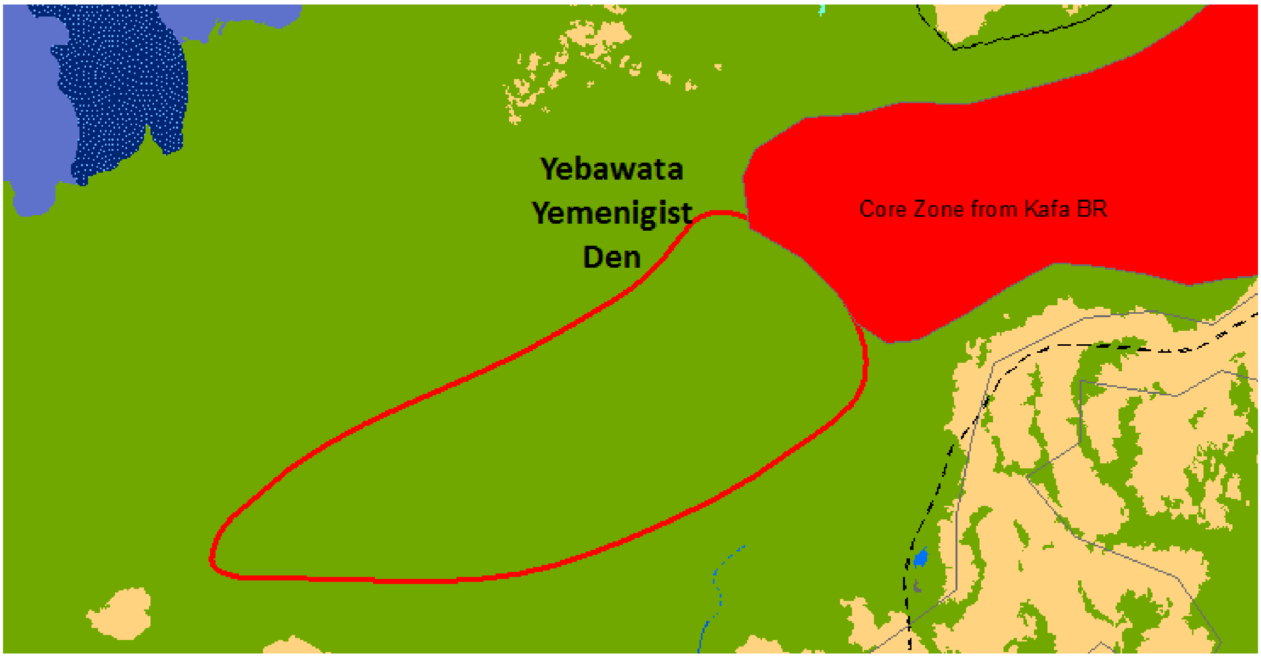


Photo of location

Present Vegetation	Mountain forest
Present land use	Selective cutting, collection of fire wood, honey collection
Description	Mountainious forest adjacent to southern floodplain on very steep slopes (>30°); enlarge the present core zone from Kafa BR
Function/ objective	Stabilizing slopes adjacent to southern floodplain
Size [ha]	480
Kebele	Southern Floodplain: Yesha, Yemenigist Den

Location: 35°55'9,077"E 7°31'15,697"N | on Vegetation Map (Map 20)

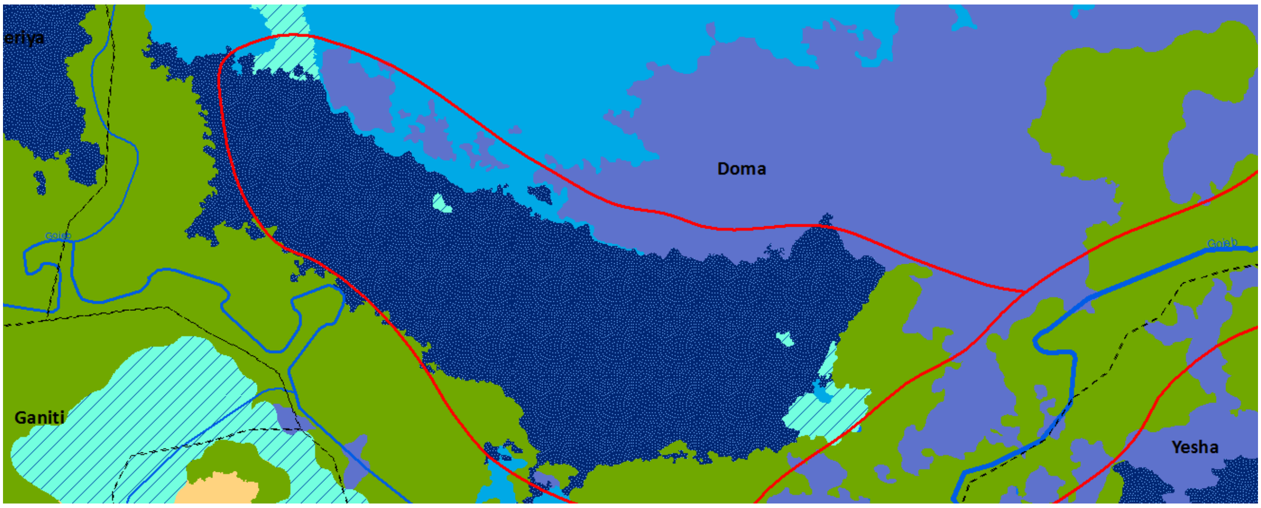


Photo of location

Present Vegetation	Arundo donax - Melanthera scandens forbs | Hyparrhenia dregeana - Cyperus latifolius forbs | Cyperus latifolius - Vigna pakeri pasture | Cyperus latifolius - Ludwigia abyssinica forbs
Present land use	Very low cattle grazing, path connecting the northern floodplain with the southern floodplain
Description	Unfragmented undisturbed wetland vegetation on the northern floodplain, high groundwater discharge, present BR status is buffer zone
Function/ objective	Connect the habitats from the southern floodplain with the northern floodplain
Size [ha]	270
Kebele	Southern Floodplain: Yesha, Yemenigist Den

2. *Buffer Zone of Gojeb*

Location: 36°1'14,88"E 7°31'30,039"N | on Vegetation Map (Map 20)

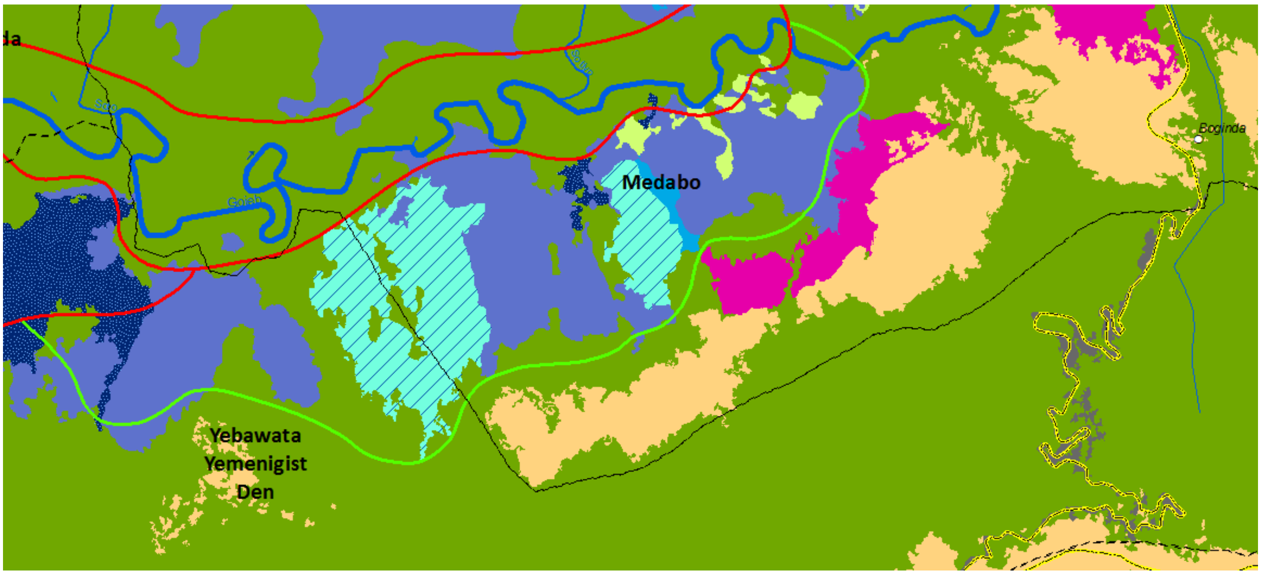

Gojeb
Medabo
Boginda
Yebawata
Yemenigist
Den

Photo of location

Present Vegetation	Hyparrhenia dregeana - Cyperus latifolius forbs | Cyperus latifolius - Ludwigia abyssinica forbs | Waterlogged meadow | Riparian forest
Present land use	Low cattle grazing, cut and carry, collection of construction material
Description	Seasonal inundation, evidence of hippopotamus and African buffalo

Objective	Support sustainable grazing
Measure	Develop sustainable grazing management concept
Size [ha]	760
Kebele	Southern Floodplain: Medabo, Yemenigist Den

Location: 35°55'15,847"E 7°32'9,9"N | on Vegetation Map (Map 20)

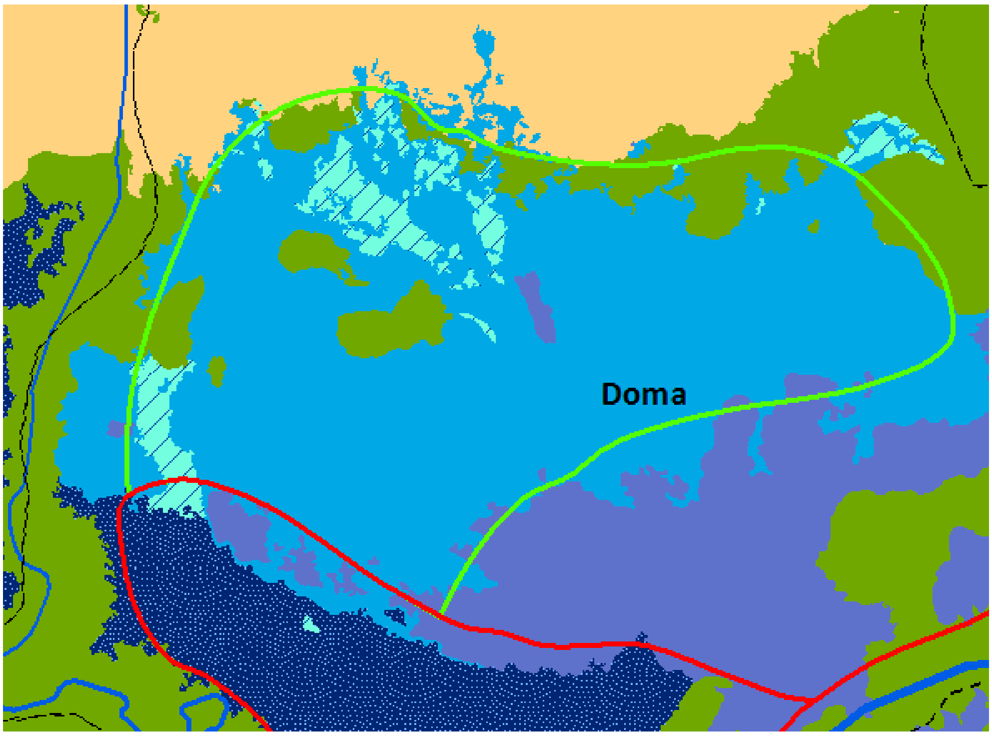


Photo of location

Present Vegetation	Cyperus latifolius - Vigna pakeri pasture | Cyperus latifolius - Ludwigia abyssinica forbs
Present land use	Intense cattle grazing, cut and carry, collection of construction material | at the northern edge land conversion
Description	Highly disturbed wetland vegetation (change of structure and composition) | land conversion → encroaching into the wetland
Objective	Support sustainable grazing, assign area for land conversion for sustainable agriculture
Measure	Develop sustainable grazing management concept, discuss if a participatory agriculture approach is possible | no biophysical constraints to utilize land for cultivation
Size [ha]	500
Kebele	Northern Floodplain: Doma

Location: 35°57'46,791"E 7°34'16,507"N | on Vegetation Map (Map 20)

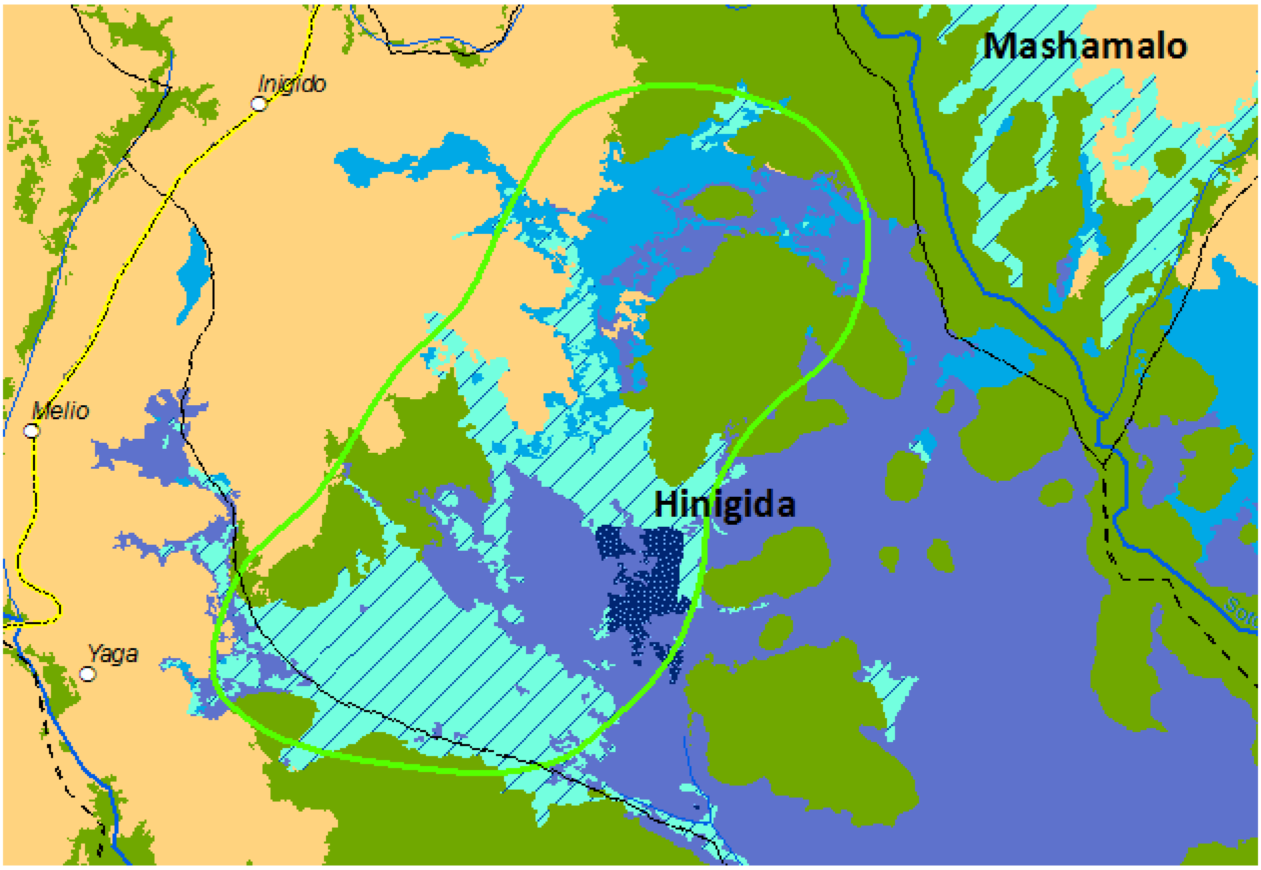


Photo of location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Hyparrhenia dregeana - Cyperus latifolius forbs | Hyparrhenia dregeana - Cyperus latifolius forbs | forest
Present land use	Medium - Intense cattle grazing, cut and carry, collection of construction material | at the northern edge land conversion
Description	Disturbed wetland vegetation (change of structure) | land conversion → encroaching into the wetland, selective cutting for construction and as firewood
Objective	Support sustainable grazing | assign area for land conversion for sustainable agriculture | alternatives for forest exploitation
Measure	Develop sustainable grazing management concept | no biophysical constraints to utilize land for cultivation | establish community plantation
Size [ha]	730
Kebele	Northern Floodplain: Hinigida

Location: 36°0'27,101"E 7°34'22,976"N | on Vegetation Map (Map 20)

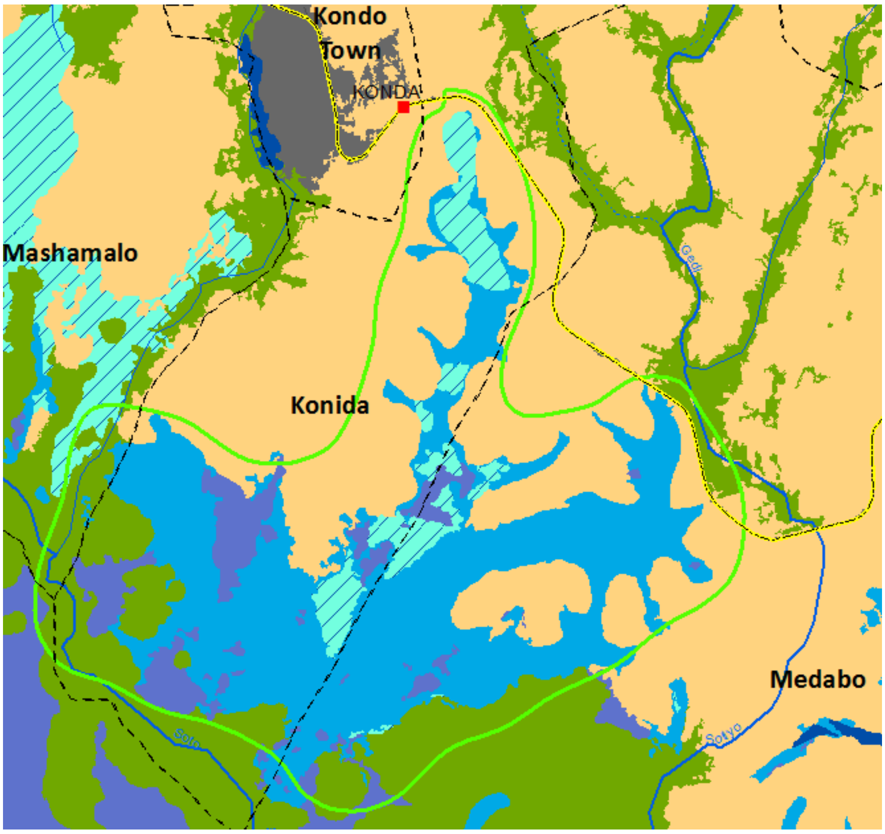


Photo of location

Present Vegetation	Cyperus latifolius - Vigna pakeri pasture | Cyperus latifolius - Ludwigia abyssinica forbs | Hyparrhenia dregeana - Cyperus latifolius forbs
Present land use	Moderate cattle grazing, cut and carry, collection of construction material | along wetland tongue, land conversion
Description	Disturbed wetland vegetation (change of structure and composition) | land conversion → encroaching into the wetland
Objective	Support sustainable grazing, assign area for land conversion for sustainable agriculture
Measure	Develop sustainable grazing management concept | biophysical constraint in dry season to utilize land for cultivation = insufficient water (might be overcome with pumps)
Size [ha]	870
Kebele	Northern Floodplain: Konida, Medabo

Location: 36°2'24,194"E 7°33'21,563"N | on Vegetation Map (Map 20)

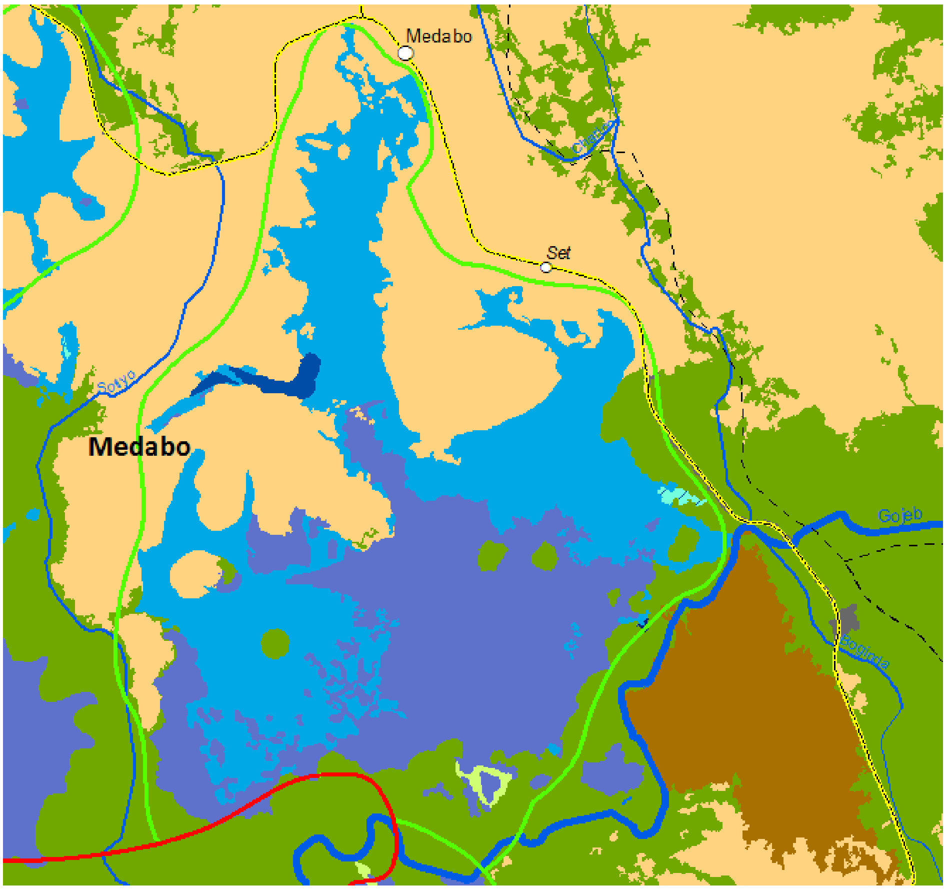


Photo of location

Present Vegetation	Hyparrhenia dregeana - Cyperus latifolius forbs | Cyperus latifolius - Vigna pakeri pasture | frest patches
Present land use	Intense cattle grazing, cut and carry, collection of construction material | along the wetland edge evidence of land conversion
Description	Highly disturbed wetland vegetation (change of structure and composition) | land conversion → encroaching into the wetland
Objective	Support sustainable grazing, assign area for land conversion for sustainable agriculture
Measure	Develop sustainable grazing management concept | no biophysical constraints to utilize land for cultivation
Size [ha]	950
Kebele	Northern Floodplain: Medabo

c. Chidi

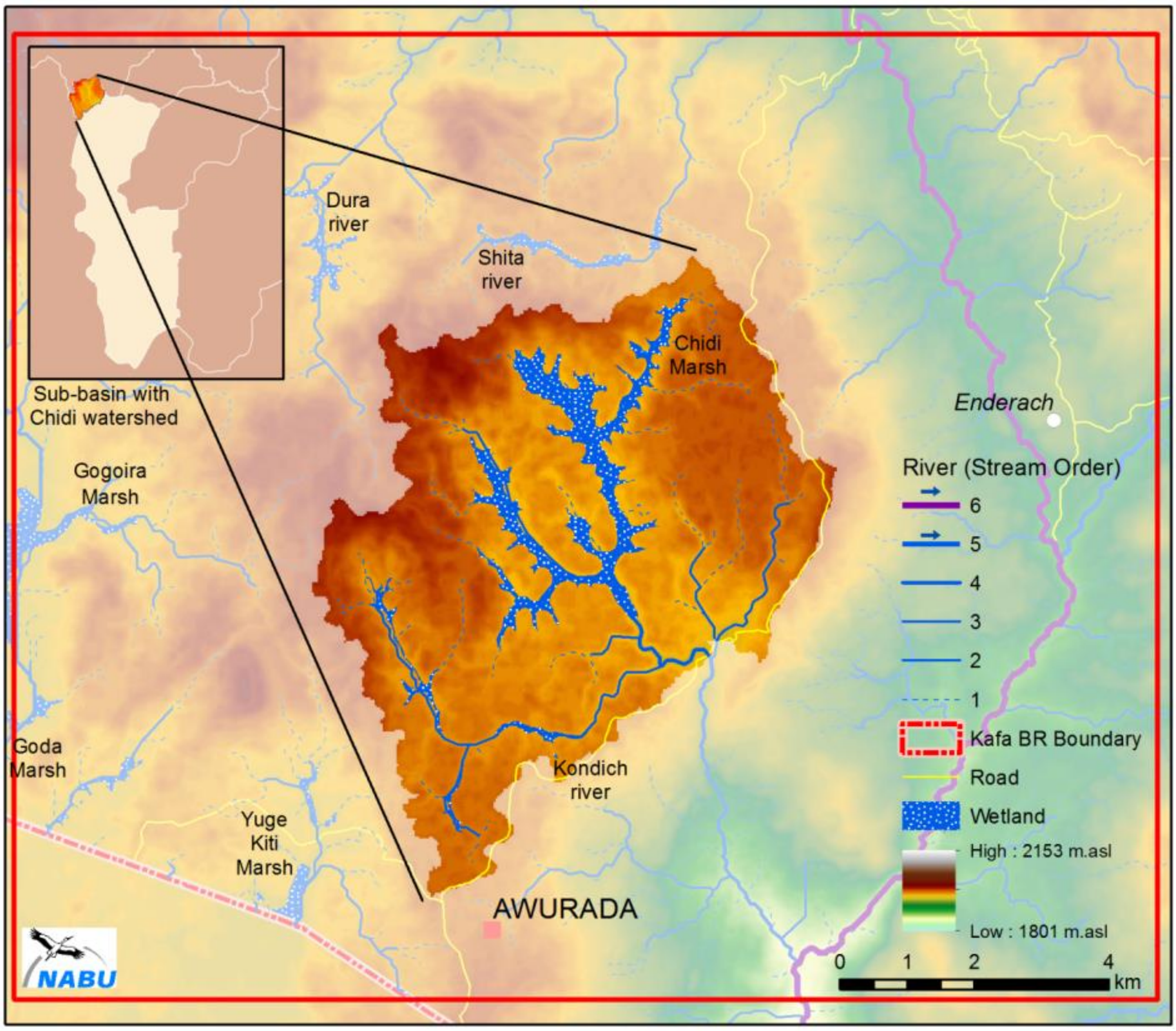
Chidi Wetland is located in a narrow stretched valley surrounded by steep forested slopes. According to the Topographic maps of EMA, the wetland is framed by Boka, Gecha, Kejo and Wutiwuti forest. Change detection from satellite imagery (2008, 2010, 2011) and the comparison with the Topo maps indicate high deforestation rates. A coffee investment area has been established in the north east of the wetland. In the south, agricultural land is bordering the wetland, but not yet encroaching it.

Chidi wetland stretches from north to south around 6 km and from west to east 3 km. The mean altitude is 1,888 m.a.s.l. and it is located in the upper course at the edge of the watershed. The landscape position indicates the Chidi as a headwater wetland (with only first and second order streams) which conflates with Dincha river. It contributes to the elongated Dincha basin which stretches around 63 km from north to south, far out of the Kafa BR boundary. To be able, to describe the sub-basin according to its morphometric character, the sub unit and smallest division for a watershed was derived from the DTM. Thus, the sub-basin covers only the wetland and its tributaries. Accordingly, the proportion of the wetland in relation to the catchment is higher than in all other pilot sites (7.15%). It is slightly inclined from the north to the south, although the wetland surface is even and no open water course was observed inside the wetland during field work. The only pour point is located at the southern end, 3 km southwards of the church Beha Giorgis.

Outstanding finding are the considerable peat stocks within Chidi wetland.

i. Hydrology/ Topography

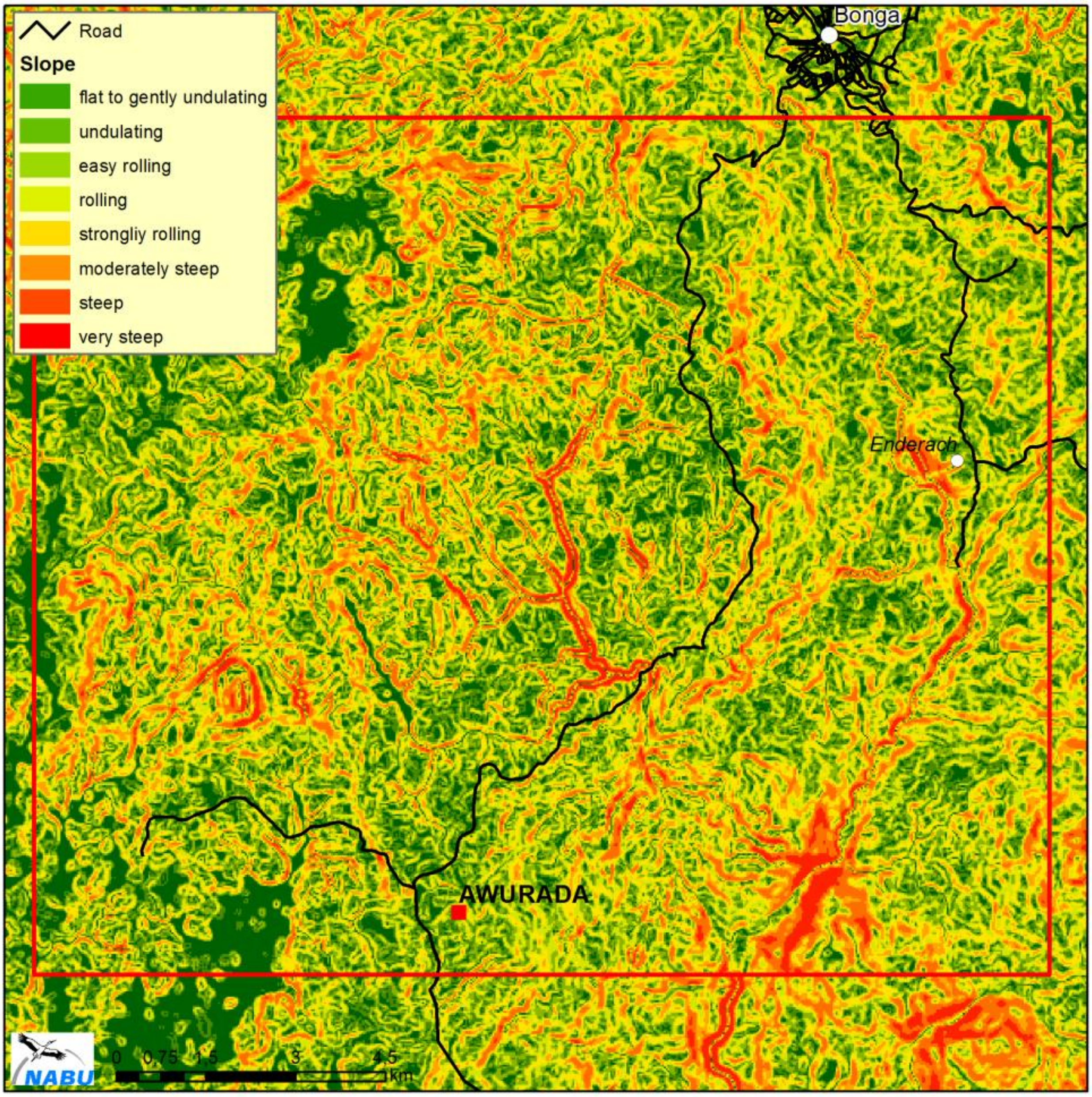
Chidi wetland is situated in the Omo-Gibe basin, the capital Awurada (Chiri) is located at the southern edge. The eastern border of the watershed is encircled by the Bonga – Awurada road. Adjacent wetlands like Yuge Kiti Marsh, Manmecho, Gogoira Marsh belong to the neighbouring Sherma basin. Other wetlands sharing the same sub-basin can probably be found in the south, out of the Kafa BR.



Map 23: Sub-basin (watershed) of Chidi wetland

The sub-basin has a dendritic drainage, with tendency of a centripetal hydrodynamic accumulating to the Dincha river. Generally, water runs from north to south but within the wetland there is a diffuse multidirectional flow. The wetland is fed by surface water run–off from the slopes and precipitation, a spring was located in the very north of the wetland. Water loss is dominated by the channelled outflow and seepage to underlying ground water. Therefore, Chidi wetland can be regarded as source system.

The slope gradient map of Chidi wetland highlights the very steep slopes surrounding the central parts of the wetland. Furthermore, the watershed divide can be identified upslope of the wetland. Due to the narrow valley it is not easy to recognize that the wetland itself is more or less flat. The very flat area in the north-west is the adjacent Manmecho Marsh and the vast flat area in the south, west of Awurada is the Yuge Kiti Marsh.



Map 24: Slope map of Chidi wetland (red square identifies the map extract showing Chidi wetland)

The morphometric characters of Chidi wetland look as below.

Table 19: Morphometric parameters of Chidi wetland

Order of Stream	Number of Streams	Bifurcation Ratio	Total Stream length [km]	%	Average Stream length [km]	Length Ratio
I	34		32,409113	0,30249312	0,953209	
II	6	5,67	15,386478	0,14361096	2,564413	2,69

III	2	3,00	9,195394	0,08582597	4,597697	1,79
IV	1	2,00	2,769632	0,02585059	2,769632	0,60
V				0		
VI				0		
Σ	43		59,760617			
Ø		3,6	1,4			1,70

The morphometric parameters are comparable to those from the other pilot sites, except that it has the lowest stream length ratio with a higher variation (1.70) compared with Gojeb wetland (1.96) and Alemgono wetland (1.87). This is partly due to the lower stream order found in Chidi wetland (4th stream order) but it is also an indication of the higher variation in slope and topography within the sub-basin.

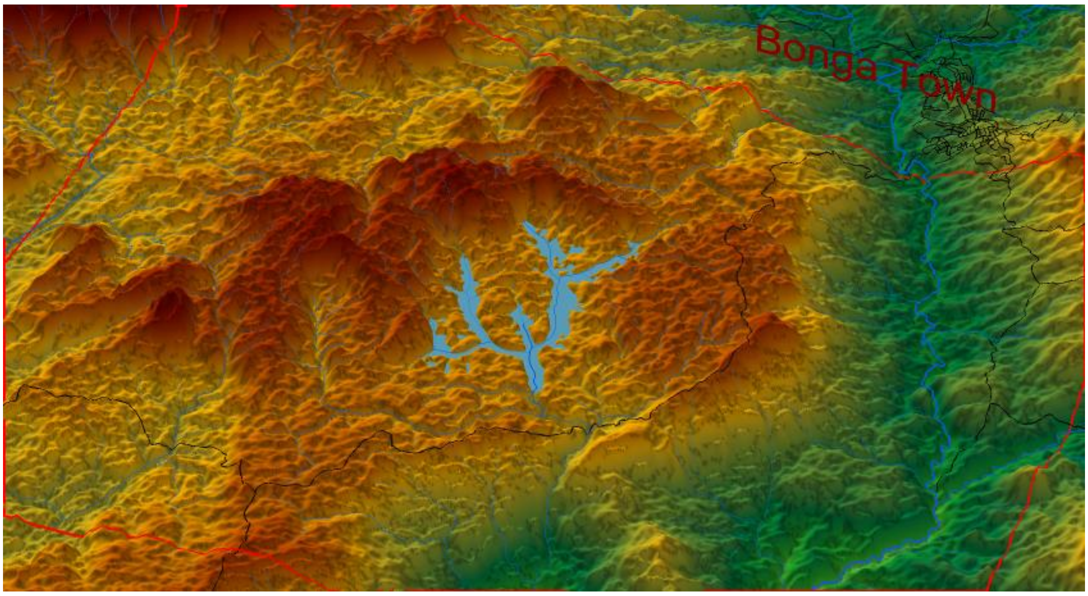


Figure 45: 3D view of Chidi wetland (vertical exaggeration x3) with modelled river network (blue) and main roads (black)

The 3D figure above gives a good impression of its position within the landscape. Here it becomes obvious that the main water source is precipitation with lateral surface transport (less channelled). Without taking into account the outflow in the south, Chidi wetland is located in an almost closed basin. Due to the high mean altitude (1,900 m.s.l.) the contribution of groundwater is probably less important. It is assumed that precipitation and surface inflow is higher than the potential evapotranspiration (PET) during the growing season which promotes the accumulation of organic matter; this retards drainage and paludification is promoted. The occurrence of moderately decomposed peat[29] on the terrain surface suggests that the wetland is in widely waterlogged throughout the year. Stable high water tables allow the sequestration of presumably substantial peat accumulations, which also form the characteristic vegetation formation of the wetland.

[29] According to Joosten & Clark 2002, peat can be defined as „a sedentarily (in-situ) accumulated material comprising of at least 30% dry mass) of dead organic matter“

The hydrodynamic energy is low, considering that there are no channelled inflows and only one pour point with a low water level. Accordingly, main water loss is by saturation overland flow and seepage to underlying ground water. Perennial steams within the wetland could not be detected. Due to the low gradient, only fine sediments can be transported; if any. This nutrient trap, under reducing conditions, strongly favour obligate wetland species(M.M. Brinson 1993).

Chidi wetland can be classified as organic soil flat, or headwater ombrotrophic bog mainly fed by precipitation and lateral surface water with contribution to groundwater recharge.

ii. Vegetation

In Chidi Wetland vegetation classes are adapted to the occurring organic soils, these are Cyperus denudatus - Thelypteris confluens forbs mainly in the centre and the north of the wetland, Cyperus latifolius - Ludwigia abyssinica forbs in the centre and in the south in presumably nutrient richer sites and Cyperus latifolius - Berula erecta edge vegetation on the border of the wetland, forming a typical edge vegetation (Map 25).

Table 20: Vegetation & Map unit for Chidi pilot site

Vegetation unit	Map unit	Area in ha
***Cyperus denudatus - Thelypteris confluens* forbs**	Cyperus denudatus forbs	169,16
***Cyperus latifolius - Ludwigia abyssinica* forbs**	Cyperus latifolius forbs	598,52
***Cyperus latifolius - Berula erecta* edge vegetation**	Edge vegetation	79,08

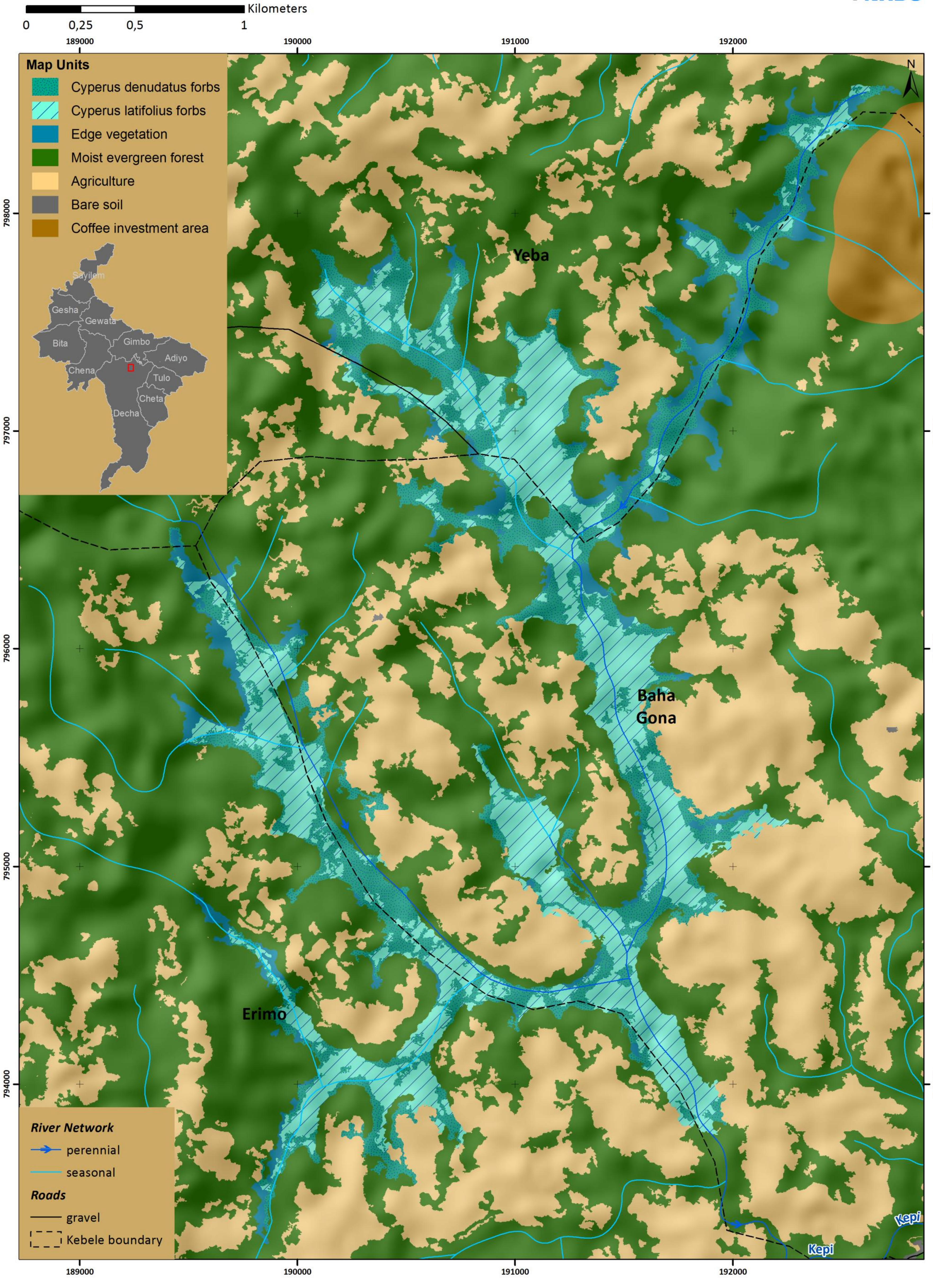
Table 21: Species list and site description of Chidi pilot site

species	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Berula erecta	Apiaceae	mashy area	x			shallow water	
Melanthera scandens	Asteraceae	swamp margins, river banks	x		?		
Impatiens ethiopica	**Balsaminaceae**	**river stream bank,swamps marshes, ditches, damp spots**					
Cyperus denudatus	**Cyperaceae**	**swamps, swamp-edges, ditches, wet habitats**	**x**			**wet**	**peat formation**
Schoenoplectus corymbosus	**Cyperaceae**	**wet habitat,swamps,pools,lake margin**	**x**			**standing water**	**peat formation**
Cyperus latifolius	**Cyperaceae**	**swamp**	**x**			**wet ground**	**raw material, roof thatching**
Phyllanthus boehmii	**Euphorbiaceae**	**marshes, swampy grassland, wet banks**	**x**				
Plectrantus edulis	**Lamiaceae**	**marshy areas or cultivated**	**x**				**grazing weed**
Dissotis canescens	**Melastomataceae**	**seasonally water-logged grassland, wet flushes**	**x**			**water logged**	

species	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Epilobium salignum	**Onagaceae**	**marshed, swampy places**	**x**				
Ludwigia abyssinica	**Onagraceae**	**swampy ground, near rivers lakes**	**x**				
Persicaria strigosa	**Polygonaceae**	**marshy ground,swamps, lake shores, wet grassland**					
Persicaria decipiens	**Polygonaceae**	**roads, river banks**					
Alchemilla pedata	**Rosaceae**	**moist groun, grassland**	**x**				
Galium scioanum	**Rubiaceae**	**damp wet swampy places**					
Thelypteris confluens	Thelypteridaceae	swamps,floating bogs?	x			wet	peat formation

Figure 46: Undisturbed Vegetation in Chidi Wetland (photo by F. Mundt)

Vegetation Map of Chidi Wetland



Map 25: Vegetation Map of Chidi

iii. Soil

In the wetland solely peat soils occur (Figure 47), with moderate decomposed peat in the centre indicating ongoing peat formation. Due to a more or less constant water table, low flow velocities and fine sediment input from the surrounding slopes, high decomposed peat or mineral rich peat is found at the wetland edges. Consequently Chidi Wetland is presumably an accumulating peatland site. Considerable peat stocks are expected.

Figure 47: Peat confirmed by organic content and thickness in Chidi Wetland (36°12'13,476"E 7°10'39,102"N | Photo: C.Tegetmeyer)

iv. Hemeroby

The wetland itself is less influenced by human intervention. The majority of interviewed locals (83%; n=6)[30] did not recognize a change (neither in size, nor in species composition) of the wetland within the last 10 years. This partly results from its inaccessibly, due to steep slopes and permanent waterlogging in most parts. The still existing forest buffer offer alternatives for grazing ("forest grazing") and support lateral and sub-surface water flow. Although the surrounding Kebeles has a relatively high population density and the capital Awurada can be reached after 6 km, the wetland can be classified as oligohemerobic.

v. Threats

The Chidi wetland itself is fairly undisturbed. But looking externally to the wetland, different directly affecting threats are observed and reported.

[30] (Dresen 2014)

An actual threat is the recently established coffee investment area (CIA) in the Boka forest (Kebele Baha Gona). According to conducted interviews in Chidi(Dresen 2014) this results in increasing grazing pressure to the wetland due to impeded forest grazing. The field team observed the application of pesticides within the plantation. Pesticides and fertilizers will easily be transported into the wetland and can directly influence the wetland and its biodiversity by eutrophication and salinization. Further extension of ICAs will increase the sedimentation and destabilize the very steep slopes. This has further implications on the microclimate and drainage, like deforestation in general. A remote sensing change detection (2008, 2010, 2011) and a comparison with the actual forest cover with the one depicted on the Topographic map, illustrate a tremendous decline in forest cover in the vicinity of Chidi wetland.

According to interviews, Chidi wetland serves as a site for collecting construction material, the supply of fresh watering and for grazing livestock. Grazing and cut & carry only exist where access to the wetland is easy (close to the road), but so far it plays a subordinate role, and does not represent a major threat at the moment. Nevertheless, further proliferation or intensification of these activities should be avoided. Other activities are not remarkably impacting the wetland.

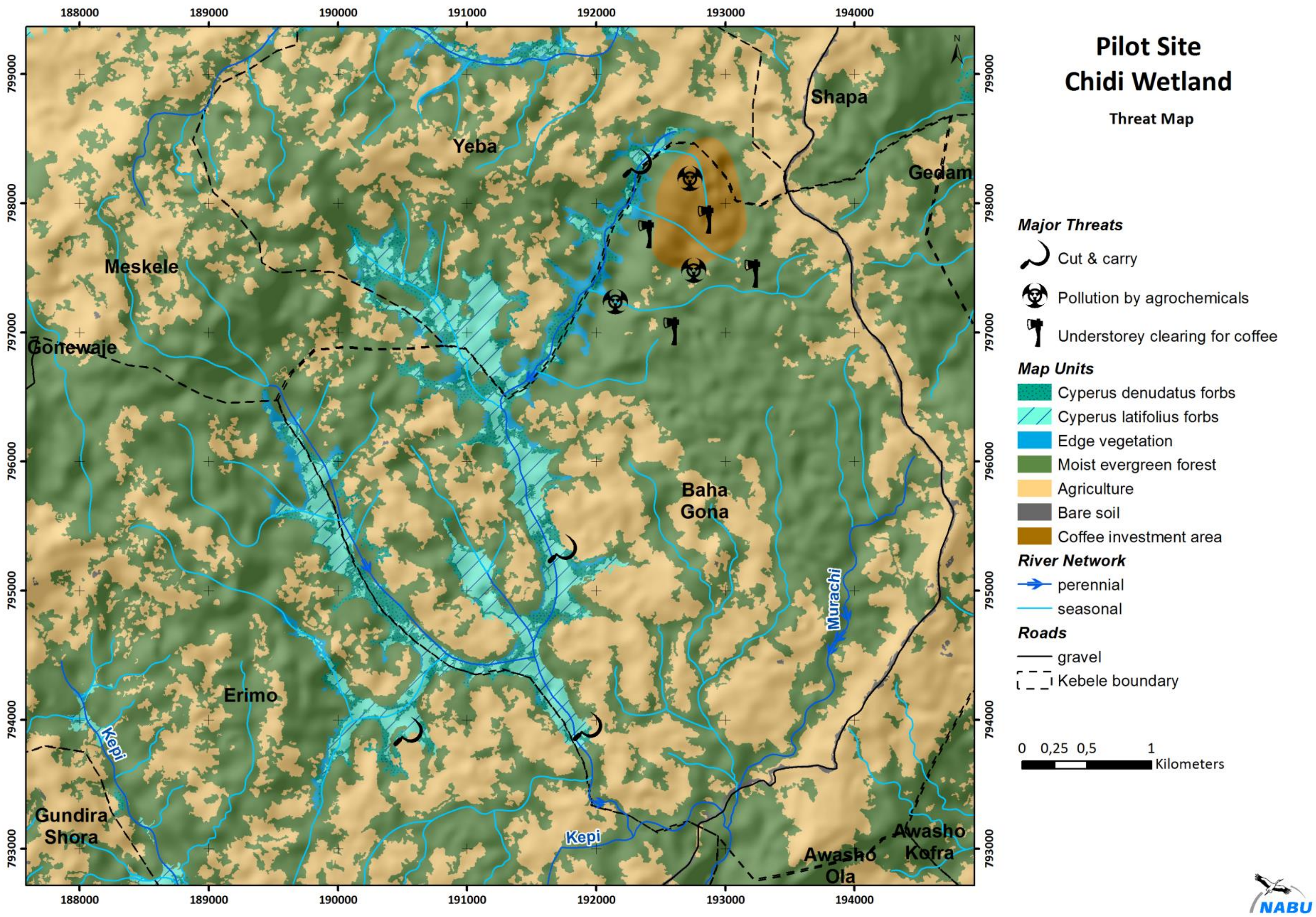
According to key informants, the biggest threats of the wetland resource are cited as population pressure, expanding grazing activities, insecure land-tenure and encroaching farming.

Figure 48: Grazing in Chidi wetland close to the Bonga – Awurada road (Photo by C. Tegetmeyer | 36°12'36,489"E, 7°10'23,41"N)

The nutrient input caused by the use of fertilizers on the surrounding arable land can be classified as low, due to the position in the landscape. Accumulated surface water only origin from forested slopes.

Chidi wetland – as an ombrotrophic bog, is particularly vulnerable to changes in drainage, because of the strong coupling between landform and hydrology and to changes in climate, because of climatic control of water balance. Once disturbed, the wetland can alter its typical characteristics very quickly, which might lead to a release of carbon. Globally, wetlands and in specific peat-forming wetlands contain large reserves of organic carbon. The contribution of accumulating peatlands as carbon sinks is controversially discussed, because the beneficial effect of this carbon accumulation is at least partially offset by release of methane. Far from this debate the 3rd IPCC assessment report(Kauppi et al. 2001) states:

“A more important mitigation measure, from the perspective of atmospheric CO_2, is the preservation of the vast carbon reserves already present (van Noordwijk et al., 1997) in peatlands. Drainage of these wetlands for agricultural or other uses results in rapid depletion of stored CO_2 (Kasimir-Klemedtsson et al., 1997).”


Pilot Site
Chidi Wetland
Threat Map
Major Threats
Cut & carry
Pollution by agrochemicals
Understorey clearing for coffee
Map Units
Cyperus denudatus forbs
Cyperus latifolius forbs
Edge vegetation
Moist evergreen forest
Agriculture
Bare soil
Coffee investment area
River Network
perennial
seasonal
Roads
gravel
Kebele boundary
0 0,25 0,5 1
Kilometers
Shapa
Gedam
Yeba
Meskele
Gonewaje
Baha Gona
Erimo
Gundira Shora
Kepi
Murachi
Awasho Ola
Awasho Kofra
188000
189000
190000
191000
192000
193000
194000
799000
798000
797000
796000
795000
794000
793000
NABU

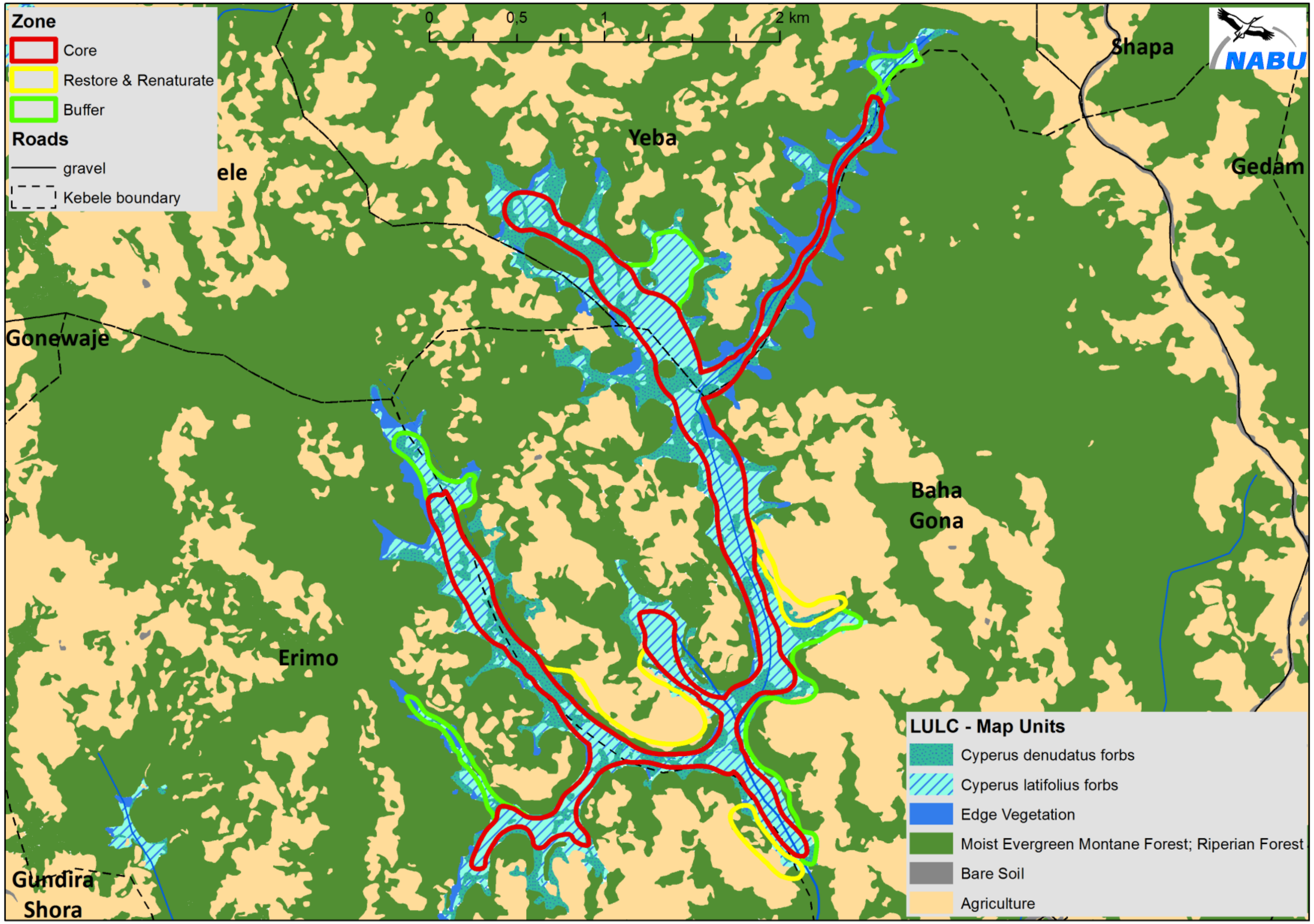
vi. Management/ Monitoring

Chidi wetland only provides physical benefits to a few local communities. An impact caused by collecting construction material could not be observed, and so far alternatives existed to graze cattle elsewhere. There are severe biophysical constraints to use the Chidi wetland as a grazing site, but if alternatives are lacking, this will happen in the foreseen future. The TLU of adjacent Kebeles (Map 27) is believed to exceed the carrying capacity in a landscape matrix of fragmented and patchy forest and intense agriculture. The trade-off between ecological conservation and the scarcity of grazing land might be overcome if forest grazing is ensured in the future, multiple sources are used (e.g. crop residues) and with proper management to allow sustainable cut and carry from Chidi wetland. The edge vegetation in general could be used for this purpose because the sediment share is higher (redox potential is less) and plant communities tend to be more productive. However edge vegetation comprised of Berula erecta should be avoided due to the toxic substances.

Wetland encroachment for agriculture should be abandoned and clear boundaries of e.g. exotic tree species are recommended. Probably, efforts to support adjacent farmers to diversify their crop production and establish agroforestry systems could be successful in minimizing farmland extension. Easy excess to markets (Awurada, Bonga) are good preconditions for fruits and vegetables. Further measures to collect rain water and to operate wells should be introduced and any irrigation with water from Chidi wetland should be avoided.

The interpretation of satellite images from different years found that all adjacent forests in the past and present are subject to severe logging, followed by conversion to agriculture. In the terms of wetland protection, efforts should be undertaken to release the pressure on the forest. According to the interviews, fuel wood is seen as the most limited resource in the future! This should serve as encouragement for further selection of PFM sites, if applicable, establish community plantations and develop strategies to overcome the very likely fuel wood scarcity (e.g. use of dung, dissemination of fuel efficient stoves, community kitchens to use the economy of scale).

According to collated and evaluated information, a proposal of zonation – open for discussion – will be showen below. It should be understood as a baseline for a participatory process with all stakeholders and improved by further research. A spatialization was not possible in all cases due to missing ground truths of the specific sites. Photo documentary was not available for all proposed sites, (all photos are taken during the 1st, 2nd, 3rd field visit, mid – end of dry season). The legend of the zonation overview will be valid for the detail extracts.



Map 26: Proposed Zonation of Chidi Wetland

1. Core Zones of Chidi

Location: 36°12'22,402"E 7°10'44,637"N | on Vegetation Map (Map 25)

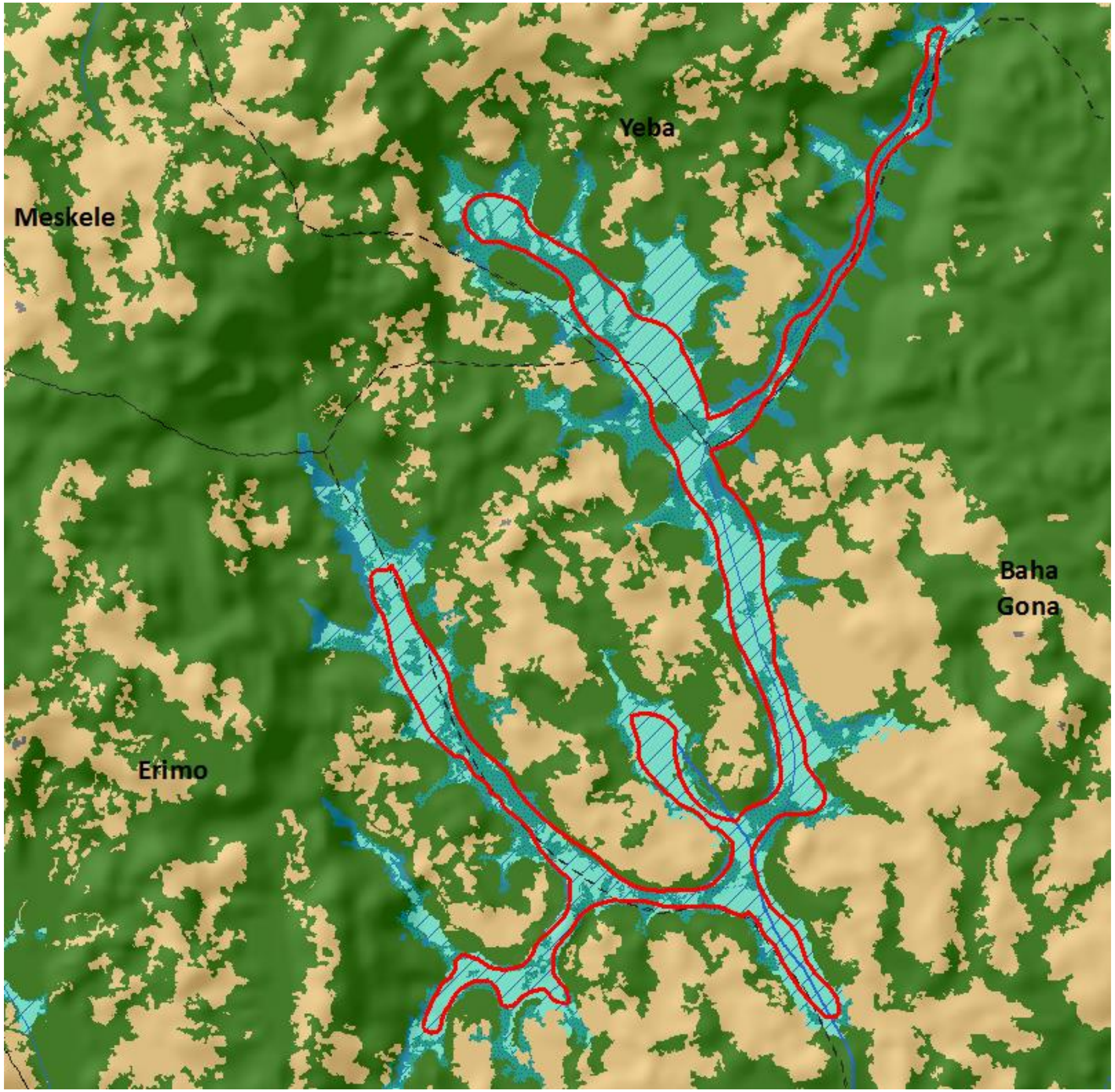

Yeba
Meskele
Baha
Gona
Erimo

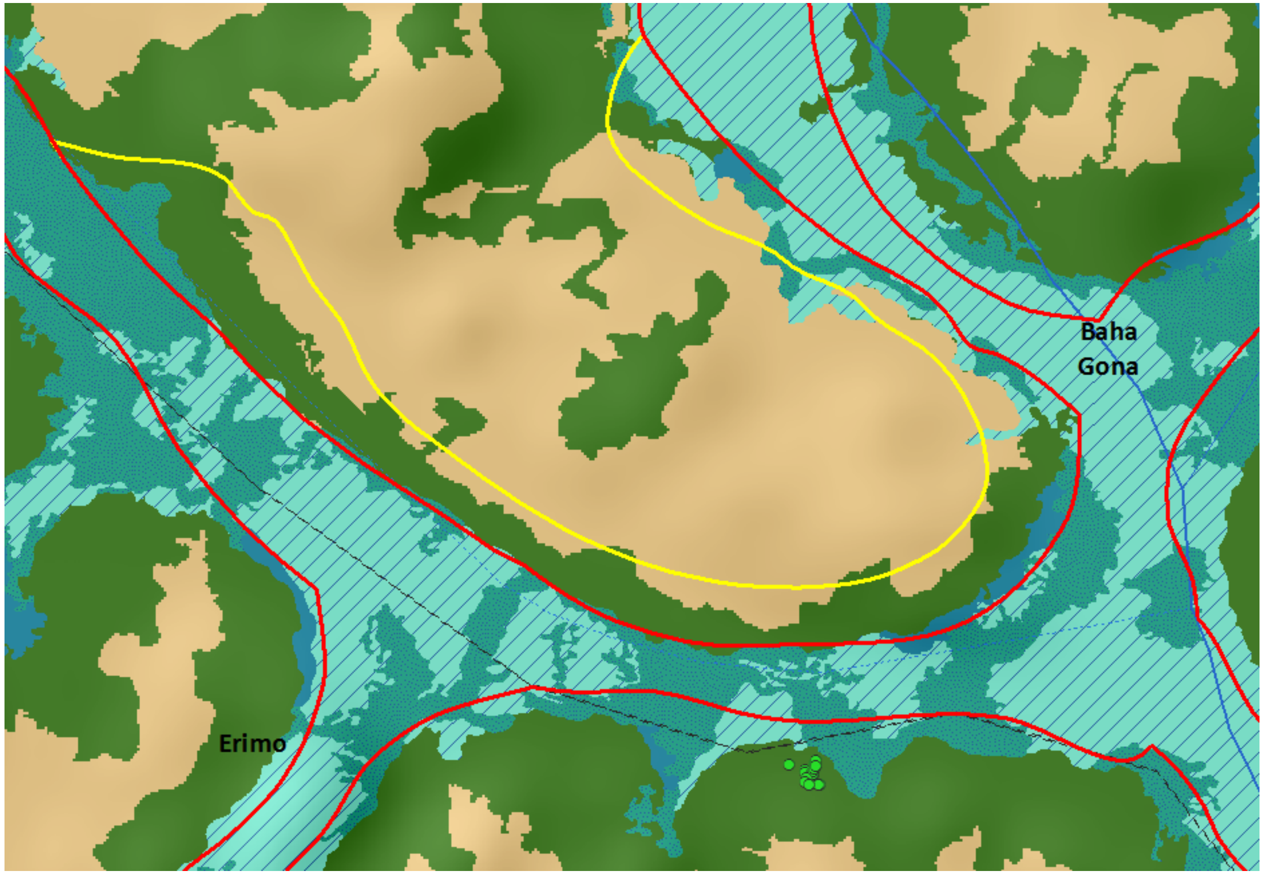
Photo of location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus denudatus - Thelypteris confluens forbs | vegetation_unit Cyperus latifolius - Berula

	erecta edge vegetation | forested outcrop (not waterlogged)
Present land use	Probably some minor collection of construction material
Description	Protection of obligate wetland species, preservation of considerable peat stock
Function/ objective	Habitat of keystone species, water source
Size [ha]	133
Kebele	Erimo, Meskele, Yeba, Baha Gona

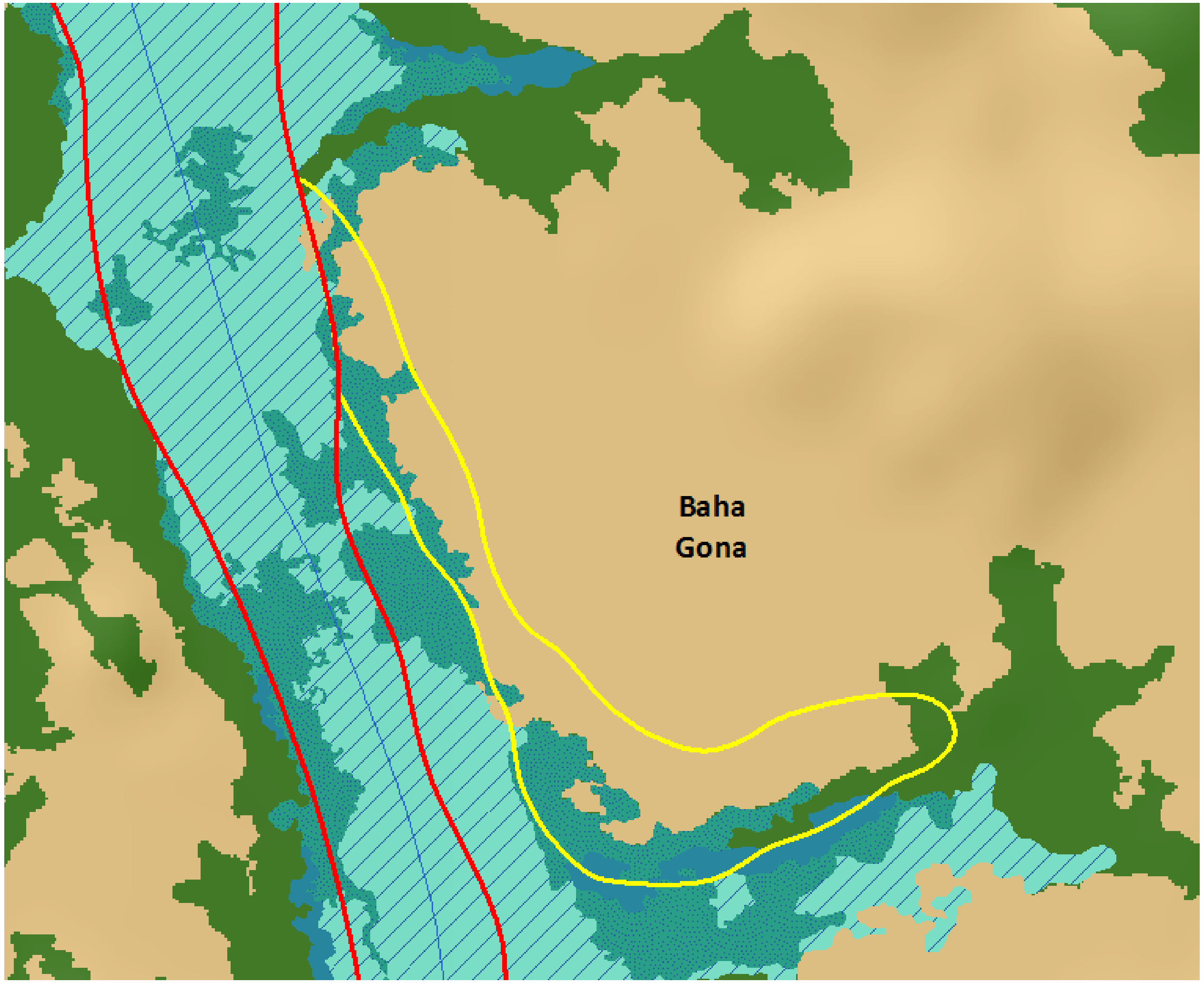
2. Area to restore and renaturate

Location: 36°12'16,828"E 7°10'45,166"N | on Vegetation Map (Map 25)



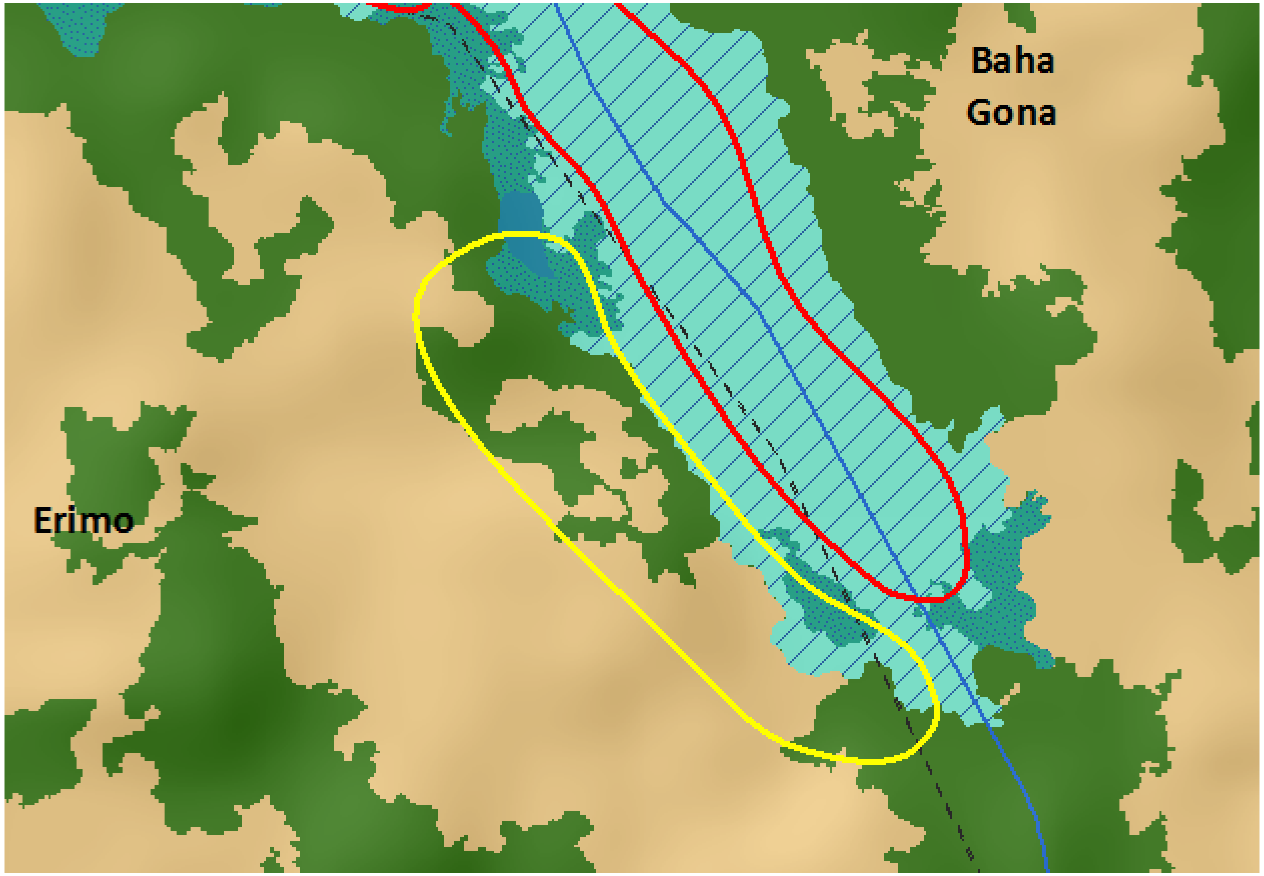
Present Vegetation	Narrow stripe of remnant forest, if any; agriculture
Present land use	agriculture
Description	Area deforested within the last 10 years
Actual threat	Further encroachment to the wetland
Measure	Plant tree buffer along the wetland vegetation border
Size [ha]	12
Kebele	Baha Gona

Location: 36°12'33,115"E 7°11'13,114"N | on Vegetation Map (Map 25)



Present Vegetation	Narrow strip of remnant forest, if any; agriculture
Present land use	agriculture
Description	Area deforested within the last 10 years
Actual threat	Further encroachment to the wetland
Measure	Plant tree buffer along the wetland vegetation border
Size [ha]	6
Kebele	Baha Gona

Location: 36°12'30,208"E 7°10'26,975"N | on Vegetation Map (Map 25)



Present Vegetation	Narrow strip of remnant forest; agriculture
Present land use	agriculture
Description	Area deforested within the last 10 years, recent slash and burn activity

Actual threat	Further encroachment to the wetland
Measure	Plant tree buffer along the wetland vegetation border
Size [ha]	6
Kebele	Erimo

3. Buffer Zone of Chidi

Location: 36°12'34,844"E 7°10'54,352"N | on Vegetation Map (Map 25)

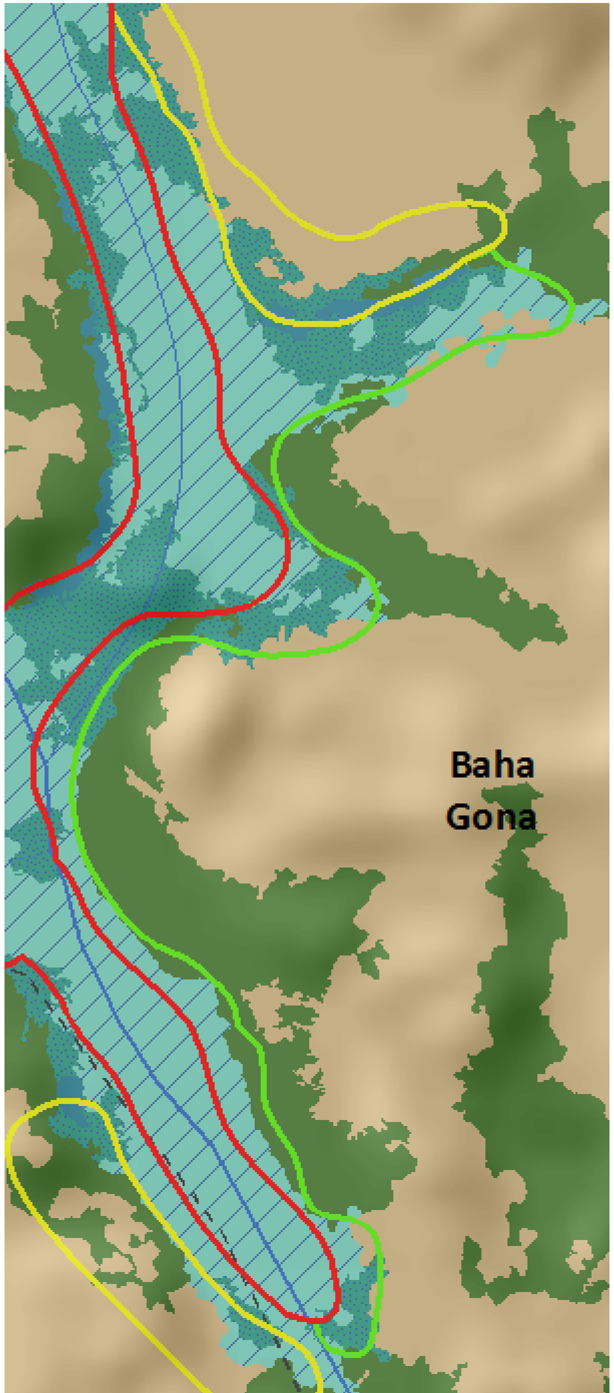

Baha
Gona

Photo of location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus denudatus - Thelypteris confluens forbs
Present land use	Perhaps low cattle grazing, cut and carry, collection of construction material
Description	High water table, evidence of peat, vegetation community without

	Berual erecta, average population density, moderate TLU
Objective	Area for cut and carry, collection of construction material
Measure	Develop sensitive management of cut and carry
Size [ha]	16
Kebele	Baha Gona

Location: 36°12'34,844"E 7°10'54,352"N | on Vegetation Map (Map 25)

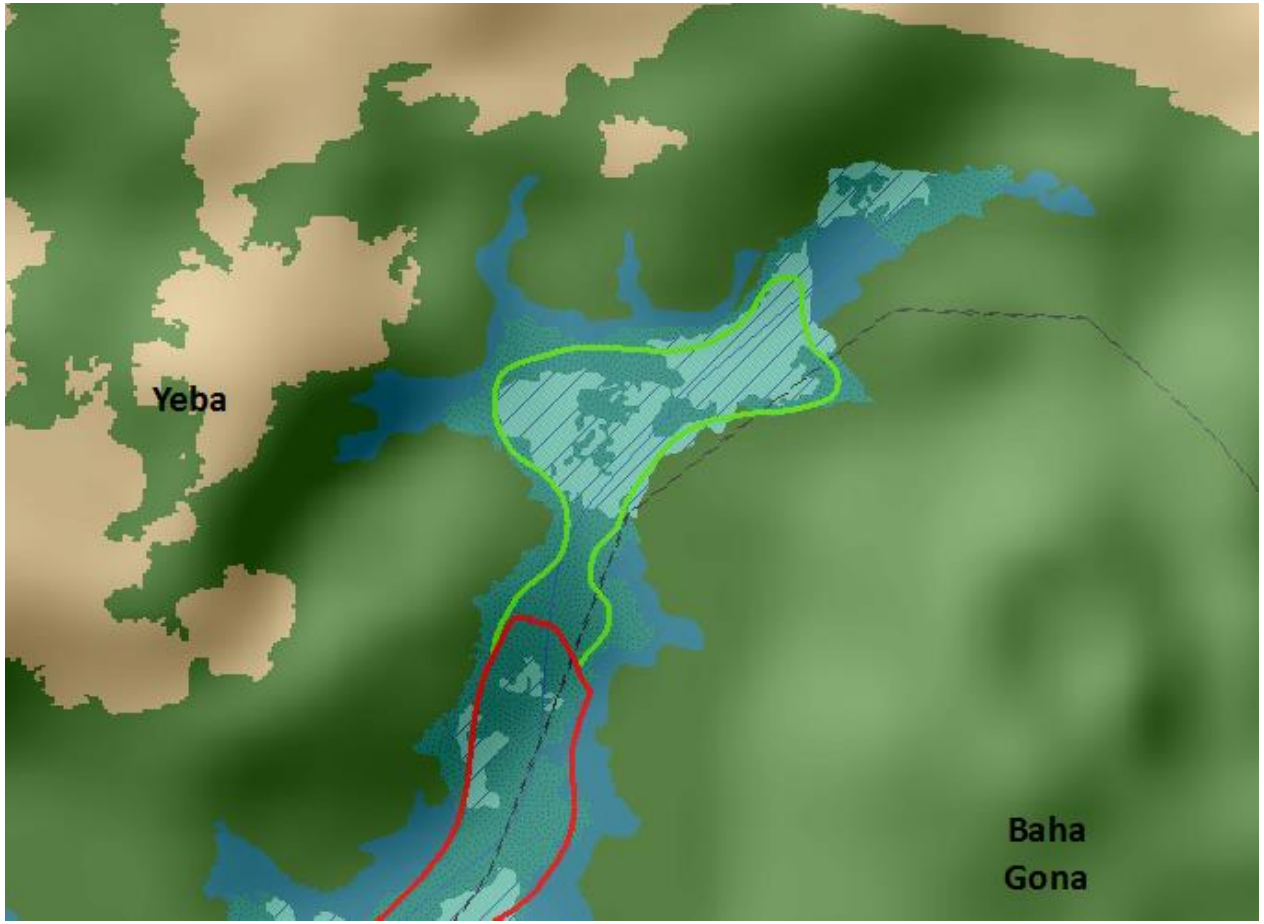
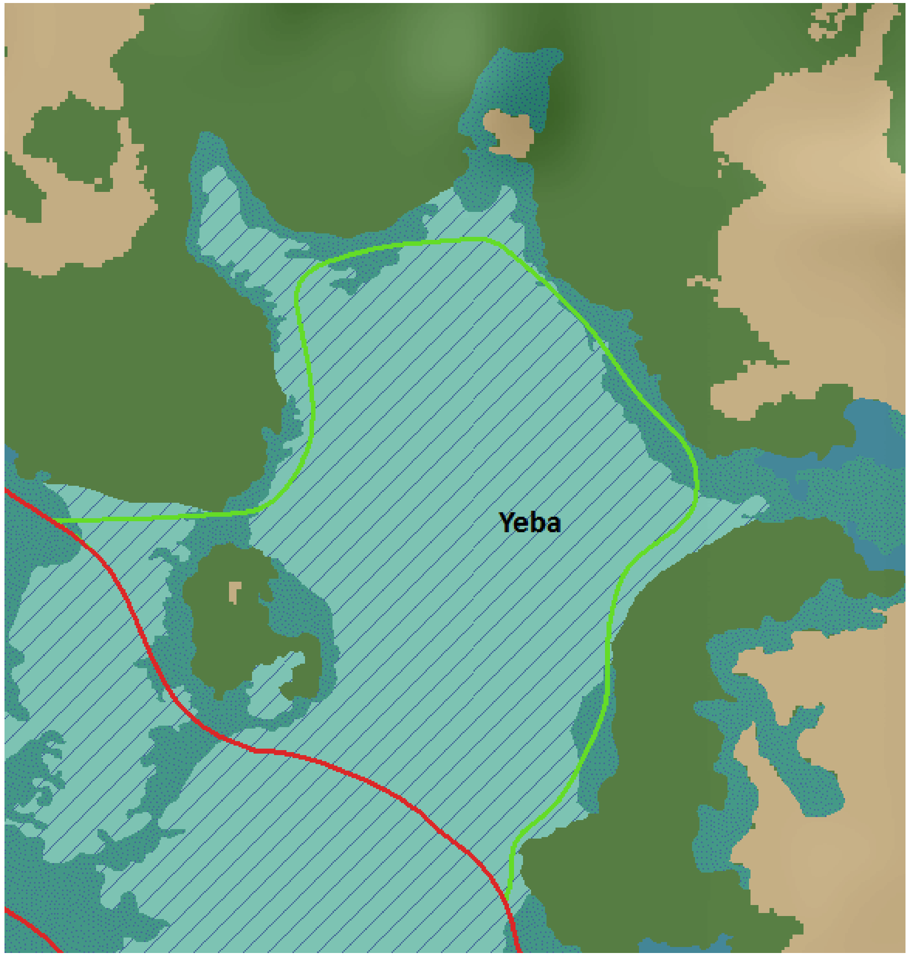


Photo of location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus denudatus - Thelypteris confluens forbs

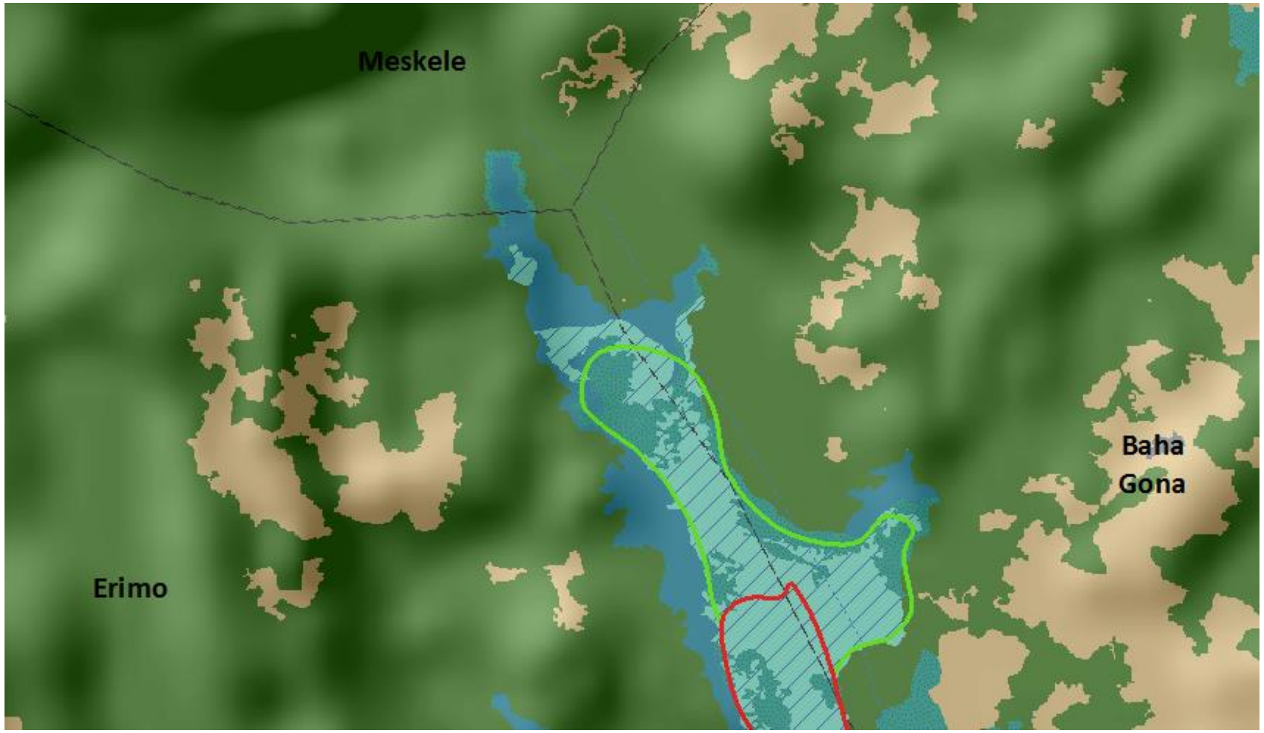
Present land use	Cut and carry
Description	High water table, evidence of peat, vegetation community without Berula erecta, adjacent to CIA | possible constraint – difficult to access, steep slopes,
Objective	Area for cut and carry, as addition to forest grazing
Measure	Develop sensitive management of cut and carry
Size [ha]	1
Kebele	Yeba, Baha Gona

Location: 36°12'11,915"E 7°12'13,168"N | on Vegetation Map (Map 25)



Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs	Cyperus denudatus - Thelypteris confluens forbs
Present land use	Cut and carry
Description	Vegetation community without Berual erecta
Objective	Area for cut and carry, as addition to forest grazing
Measure	Develop sensitive management of cut and carry
Size [ha]	10
Kebele	Yeba

Location: 36°11'27,337"E 7°11'35,074"N | on Vegetation Map (Map 25)



Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus denudatus - Thelypteris confluens forbs
Present land use	Cut and carry
Description	Vegetation community without Berual erecta

Objective	Area for cut and carry, as addition to forest grazing
Measure	Develop sensitive management of cut and carry
Size [ha]	7
Kebele	Erimo, Baha Gona

Location: 36°11'34,653"E 7°10'42,26"N | on Vegetation Map (Map 25)

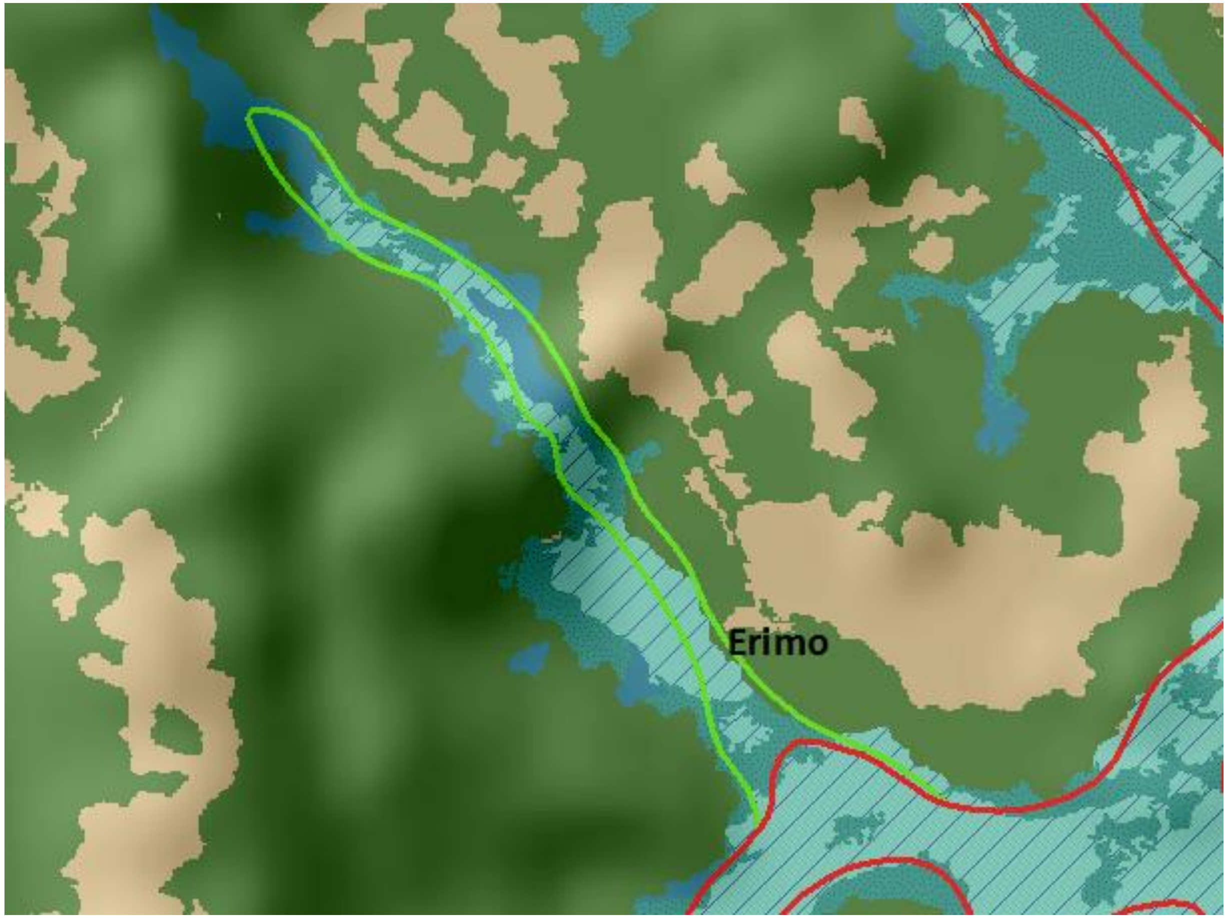


Photo of location

Present Vegetation	Cyperus latifolius - Ludwigia abyssinica forbs | Cyperus denudatus - Thelypteris confluens forbs

Present land use	Probably collection of construction material
Description	Vegetation community without Berual erecta
Objective	Area for cut and carry, as addition to forest grazing
Measure	Develop sensitive management of cut and carry
Size [ha]	4
Kebele	Erimo, Baha Gona

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7. Appendix

Table 22: Calculation of Evapotranspiration (EVT) after TURC for Kafa BR

Wushwush climate data 2009/10					
Month	T_max [°C]	T_min [°C]	T_mean [°C]	PPT [mm]	PPTday
July	23,77	13,39	18,58	109	16
August	23,65	13,16	18,405	187,3	17
Sept	24,75	12,98	18,865	6,14	20
Oct	26,4	12,43	19,415	6,5	15
Nov	28,32	11,5	19,91	2,15	7
Dec	25,45	12	18,725	4,69	12
Jan	27,56	13,67	20,615	9,08	5
Feb	26,83	13,31	20,07	11,13	12
March	27,85	14,46	21,155	113,3	6
April	27,53	14,49	21,01	198,1	15
May	25,6	14,89	20,245	267,2	26
Jun	25,01	13,58	19,295	237,4	19
sum	312,72	159,86		1151,99	
annual average	26,06	13,3216667	19,6908333		
L(t)=300 + 25t+0,05t³ = 1173,94					
mit t=annual average Tmean					
ET (nach TURC)=N/√(0,9 + (N²/L(t)²)					
ET= 843,95 mm/a					

Wushwush climate data 2010/11					

Month	T_max	T_min	T_mean	PPT	PPTday
July	22,9	13,48	18,19	111,5	16
August	23,9	13,39	18,645	200,24	19
Sept	24,9	13,32	19,11	329,87	23
Oct	25,9	12,79	19,345	137,2	11
Nov	26,9	11,7	19,3	57,3	6
Dec	27,9	11,79	19,845	63,7	7
Jan	28,9	11,46	20,18	1,9	2
Feb	29,9	11,21	20,555	10,2	1
March	30,9	13,11	22,005	86	15
April	31,9	13,1	22,5	189,9	20
May	32,9	13,87	23,385	307,5	23
Jun	33,9	13,17	23,535	281,5	20
Sum	340,8	152,39		1776,81	
annual average	28,4	12,6991667	20,5495833		

$L(t)=300 + 25t+0,05t^3 =1247,67$	
mit t=annual average Tmean	
ET (nach TURC)=$N/\sqrt{(0,9 + (N^2/L(t)^2)}$	
ET= 1037,85	

Wushwush climate data 2011/12					
Month	T_max	T_min	T_mean	PPT	PPTday
July	23,31	13,1	18,205	148,1	16
August	23,29	13,36	18,325	269,6	19
Sept	23,68	12,98	18,33	244,5	19

Oct	26,6	12,5	19,55	52,8	6
Nov	26,18	12,87	19,525	149,3	10
Dec	27,92	11,66	19,79	39,6	3
Jan	29,23	11,95	20,59	19,1	1
Feb	30,02	11,74	20,88	4	2
March	27,03	13,13	20,08	57,4	0
April	25,97	13,4	19,685	215	19
May	25,97	13,77	19,87	209,5	16
Jun	23,65	13,22	18,435	261,5	21
sum	312,85	153,68		1670,4	
annual average	26,0708333	12,8066667	19,43875		

$L(t)=300 + 25t+0,05t^3 = 1153,33$	
mit t=annual average Tmean	
ET (nach TURC)$=N/\sqrt{(0,9 + (N^2/L(t)^2)}$	
ET= 965,00 mm/a	

Figure 49: Online Questionnaire concerning threats for sub-Saharan wetlands in general and wetladns in Kafa BR in specific

Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia

NABU, The Nature and Biodiversity Conservation Union, works towards the protection of the unique environment of Kafa Biosphere Reserve with national and international partners and with the support from the German government. In the framework of the project 'Biodiversity under Climate Change: Community-Based Conservation, Management and Development Concepts for the Wild Coffee Forests' funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) within the framework of the International Climate Initiative, NABU's subcontractor geoSYS is developing scenarios especially for wetlands and river systems. In this matter, it seems to be important to collect information about future (short-, mid- and long-term) land planning and all changes which might influence the water regime within the study region.

We would like to address a few questions and would be happy, if you could spend a few minutes for answering.

Personal details

* 1. Name

2. Institution/Company

* 3. Email Address

4. Phone

5. What is your position?

7. What kind of data do you collect?

- [ ] Spatial data (with GPS or other)
- [ ] Qualitative data (about environmental/ development condition)
- [ ] Quantitative data (counting something)
- [ ] Other (please specify)

8. Where do you store the collected data?

- [ ] in paper format
- [ ] just in the final report/ working paper
- [ ] on a local PC in the office
- [ ] in a structured database where all data is hosted
- [ ] uploaded to a national database
- [ ] uploaded to a public database
- [ ] Other (please specify)

NABU geoSYS Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia

* 9. From your opinion, what are the most important functions of wetlands? (just 2 answers)

- [ ] Refuge area for wild animals and rare flora
- [ ] Water retention function – supply of fresh water
- [ ] Construction material (reeds) for local people
- [ ] Grazing area
- [ ] Cultivation during dry season (to fight famine)
- [ ] Important carbon storage
- [ ] Areas for economic growth/ development projects (e.g. cash crops)
- [ ] Refuge or reserve areas for migrants and growing population
- [ ] Other (please specify)

11. If using an international definition, which one is it? (name of the classification system)

12. Does your institution/ministry have access to a countrywide wetland database?

- Yes
- No
- I don't know.

Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia

13. Which kind of information is stored in the wetland database?

- Spatial extent
- Type of wetland
- Status
- Ecosystem services
- Unique flora and fauna
- I don't know.
- Other (please specify)

14. Is the information updated frequently?

- Yes
- No

15. Who is responsible for the database? (Leave blank if you are not sure.)

Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia

16. Do you know if there is a frequent, systematic monitoring (of spatial extent, resources, status) of

17. Are there standardized technical guidelines to collect the information?

- ◯ Yes
- ◯ No
- ◯ I don't know.

18. What kind of information is collected? (Please enter some bullet points.)

19. Especially land use policy and planning can alter the providing functions of a wetland. Is the environmental policy and the conservation strategy of Ethiopia sufficient, to set up the framework for wetland protection?

- ◯ Yes
- ◯ No
- ◯ I don't know.

Comment

20. Does a strategic land use plan exist?

- ◯ Yes
- ◯ No
- ◯ I don't know.

Comment

21. Does a national wetland policy for Ethiopia exist?

- ◯ Yes
- ◯ No
- ◯ I don't know.

Comment

23. There is a huge variety of wetlands with different functions within Ethiopia. Are there specific legislations on regional level to address local wetland problems?

- ○ Yes
- ○ No
- ○ I don't know.

24. How is the enforcement ensured? (please describe)

25. From your opinion, what would be the best way to enforce wetland legislation? (please describe)

NABU geoSYS **Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia**

26. From your opinion, what are the most relevant threats to Ethiopian wetlands? (max. 3 answers)

- ☐ Pollution
- ☐ Overgrazing
- ☐ Wetland conversion
- ☐ Water exploitation
- ☐ Fragmentation
- ☐ Other (please specify)
- ☐ Change of water regime
- ☐ Deforestation
- ☐ Exotic species
- ☐ Climate Change

27. What are the underlying reasons?

- ☐ Missing legal framework
- ☐ Missing public awareness
- ☐ Demographic pressure
- ☐ Development Pressure
- ☐ Global Warming

29. What is the most important action to protect Ethiopians' wetlands?

- Raise public awareness
- Develop a frequent monitoring system
- Form legal body / national steering committee for Ethiopians wetlands
- Development of a national wetland database
- Enhance standardized inventory of wetlands
- Other (please specify)

Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia

30. Development of a national wetland database with information about...

- Spatial extent
- List threatened/ endemic species
- Wetland status
- Soil information
- Ecosystem services
- Water regime
- Biological diversity
- Other (please specify)

31. Concerning the last question, which role could your institution/ministry take for the development of a national wetland database?

Wetland Survey for Kafa Biosphere Reserve, SNNPR, SW Ethiopia

Thank you very much for your support!

If you have provided an email address, we will send you the final results of the survey.

Table 23: Weights and TLU conversion factors of livestock (after Jahnke 1982)

Species	Liveweight [kg]	TLU conversion factor
Horses	200	0.85
Cattle	175	0.75
Mules	175	0.75
Donkeys	125	0.6
Sheep	25	0.2
Goats	20	0.15
Poultry	2.5	0.01

Table 24: Tabular extract of rivers directly infuencing wetland hydrology

Name	Velocity	Width	Depth	River flow	W/D ratio	Z_Min	Z_Max	Z_Mean	Length [m]	Min_Slope [°]	Max_Slope [°]	Avg_Slope [°]
A-Acha	0	0	0	perennial	0,0	1825,03	1847,31	1833,34	4621,57	0,03	38,36	8,24
A-Acha	0	0	0	perennial	0,0	1844,78	1849,23	1847,77	249,66	0,09	21,41	6,66
A-Acha	0	0	0	perennial	0,0	1847,24	1921,57	1897,58	4325,79	0,07	57,95	14,27
Buni	0	0	0	perennial	0,0	2438,02	2447,32	2442,43	436,43	0,43	23,88	9,05
Buni	0	0	0	perennial	0,0	2399,02	2439,26	2418,49	1615,46	0,00	29,71	6,04
Buni	0	0	0	perennial	0,0	2377,56	2401,91	2386,89	2099,04	0,03	34,05	6,44
Chercheri	0	0	0	perennial	0,0	1805,07	1814,21	1808,66	734,07	0,07	26,68	8,67
Chercheri	0	0	0	perennial	0,0	1808,39	2045,99	1901,37	3627,60	0,01	39,31	9,12

Gashi	0	0	0	perennial	0,0	1957,77	2087,96	2042,09	1322,53	0,03	53,42	16,82
Gashi	0	0	0	perennial	0,0	1880,20	1957,77	1911,64	592,86	0,11	61,51	17,47
Gashi	0	0	0	perennial	0,0	1786,48	1883,50	1831,59	2483,08	0,00	37,29	8,03
Gicha	0	0	0	perennial	0,0	1562,64	1694,81	1607,52	19009,52	0,00	54,85	10,83
Gojeb	0,6	22	0,9	perennial	24,4	1337,96	1337,96	1337,96	1323,75	0,00	0,00	0,00
Gojeb	0,6	22	0,9	perennial	24,4	1337,96	1338,79	1337,98	3238,22	0,00	4,93	0,12
Gojeb	0,7	11	0,6	perennial	18,3	1622,83	1664,79	1642,28	2172,96	0,01	44,51	6,48
Gojeb	0,7	11	0,6	perennial	18,3	1610,38	1628,26	1619,02	1061,83	0,03	34,77	7,26
Gojeb	0,7	11	0,6	perennial	18,3	1601,68	1613,19	1608,60	835,83	0,02	19,01	5,18
Gojeb	0,7	11	0,6	perennial	18,3	1588,48	1603,88	1596,02	1510,35	0,00	22,00	5,31
Gojeb	0,6	17	0,7	perennial	24,3	2037,05	2046,58	2041,47	2108,95	0,02	32,43	9,61
Gojeb	0,7	11	0,6	perennial	18,3	1661,46	1713,62	1683,66	2971,43	0,00	44,35	7,73
Gojeb	0,7	10	0,6	perennial	16,7	1713,62	1741,93	1730,36	1107,24	0,01	25,89	6,80
Gojeb	0,7	10	0,6	perennial	16,7	1925,23	2041,45	1980,87	3392,92	0,01	34,34	8,41
Gojeb	0,7	10	0,6	perennial	16,7	1796,17	1814,38	1806,98	491,81	0,00	20,52	6,34
Gojeb	0,7	10	0,6	perennial	16,7	1810,49	1817,21	1812,85	210,01	0,27	17,12	7,01
Gojeb	0,7	10	0,6	perennial	16,7	1783,71	1799,80	1795,14	549,64	0,05	22,95	7,83
Gojeb	0,7	10	0,6	perennial	16,7	1741,93	1783,71	1763,42	1029,84	0,06	54,97	11,47
Gojeb	0,7	10	0,6	perennial	16,7	1817,13	1927,05	1875,88	2220,58	0,03	30,68	8,49
Gojeb	0,7	10	0,6	perennial	16,7	1774,60	1786,04	1782,16	698,65	0,01	36,62	7,77
Gojeb	0	0	0	perennial	0,0	1493,99	1589,50	1535,38	66098,64	0,00	78,50	10,91
Gonegori	0,7	5	0,5	perennial	10,0	2143,64	2167,97	2156,23	890,83	0,06	23,88	5,39
Gonegori	0,7	5	0,5	perennial	10,0	2113,12	2144,37	2129,85	1139,00	0,01	25,69	7,34
Gonegori	0,7	5	0,5	perennial	10,0	2108,89	2113,68	2111,00	955,42	0,03	23,49	5,51
Jigi	0	0	0	perennial	0,0	1825,01	1846,52	1829,20	3977,12	0,01	91,27	14,82
Nekech	0	0	0	perennial	0,0	1745,05	1790,21	1760,73	6193,48	0,00	38,35	4,73
Nekech	0	0	0	perennial	0,0	1701,20	1782,55	1745,27	4162,87	0,00	39,93	6,36

Sor	0,8	6	0,3	perennial	20,0	2164,40	2195,83	2186,49	2333,03	0,00	42,60	7,71
Sor	0,8	6	0,3	perennial	20,0	2151,14	2170,56	2161,17	2575,46	0,03	47,69	9,91
Sor	0,8	6	0,3	perennial	20,0	2121,12	2156,66	2142,18	3992,66	0,01	37,59	9,70
Sor	0,8	6	0,3	perennial	20,0	2115,35	2124,97	2120,32	1314,03	0,01	30,53	6,52
Sor	0,8	6	0,3	perennial	20,0	2105,13	2115,96	2109,92	1369,82	0,06	43,09	9,94
Weki	0	0	0	perennial	0,0	2418,74	2447,86	2433,72	1828,15	0,01	24,55	4,61
Weki	0	0	0	perennial	0,0	2449,19	2496,15	2467,12	2013,56	0,01	21,01	4,00
Weki	0	0	0	perennial	0,0	2373,03	2418,74	2392,70	3483,48	0,01	34,27	6,41
Weki	0	0	0	perennial	0,0	2373,01	2381,49	2375,20	3703,72	0,00	43,00	7,86
Woshi	0	0	0	perennial	0,0	1775,96	1948,45	1839,25	18434,44	0,00	51,76	7,45

Table 25: Tabular extract of rivers with particular contribution as domestic water in towns and Woreda capitals

Name	Velocity	Width	Depth	River flow	W/D ratio	Z_Min	Z_Max	Z_Mean	Length [m]	Min_Slope [°]	Max_Slope [°]	Avg_Slope [°]
	0	0	0	intermittent	0	1740,9	1852,7	1813,1	1531,2	0,03	37,95	11,16
	0	0	0	intermittent	0	1562,6	1646,1	1600,0	984,2	0,02	40,62	11,16
	0	0	0	intermittent	0	1851,5	1863,4	1858,3	239,7	0,04	27,38	9,51
	0	0	0	intermittent	0	1860,7	1873,7	1868,4	720,9	0,12	32,97	10,63
	0	0	0	perennial	0	1883,9	1982,9	1925,6	4708,1	0,03	31,66	7,30
	0	0	0	perennial	0	2192,3	2308,9	2253,1	3486,0	0,01	35,47	7,62
	0	0	0	intermittent	0	1907,6	1976,7	1950,4	984,2	0,04	31,69	8,90
	0	0	0	intermittent	0	1907,6	1957,1	1937,4	805,8	0,04	23,56	8,12
	0	0	0	intermittent	0	1956,8	2091,8	2027,2	921,7	0,54	30,05	15,23
	0	0	0	intermittent	0	1956,8	2307,9	2121,2	2246,4	0,19	42,11	16,51

Barta	0	0	0	perennial	0	1659,5	1979,1	1842,0	7024,9	0,00	50,13	10,46
Besheri	0	0	0	perennial	0	1546,1	1968,8	1645,3	10388,3	0,00	44,46	9,93
Charico	0	0	0	perennial	0	1520,6	1664,6	1562,2	14529,1	0,01	58,28	10,22
Chita	0	0	0	perennial	0	1839,6	2022,0	1943,5	2934,2	0,01	43,81	10,15
Dincha	0	0	0	perennial	0	1490,9	1574,1	1552,5	15200,1	0,00	67,87	10,83
Gedi	0	0	0	perennial	0	1598,1	2267,9	1812,6	4323,2	0,02	90,24	18,18
Gedi	0	0	0	perennial	0	1541,7	1600,2	1565,8	3195,2	0,00	36,16	7,51
Gojeb	0,6	22	0,9	perennial	24,44	1307,8	1307,8	1307,8	263,9	0,00	0,00	0,00
Gojeb	0,6	22	0,9	perennial	24,44	1307,8	1307,8	1307,8	569,4	0,00	0,00	0,00
Gojeb	0,6	22	0,9	perennial	24,44	1307,8	1307,8	1307,8	938,5	0,00	0,00	0,00
Kajeti	0	0	0	perennial	0	1562,2	1569,3	1565,4	744,6	0,01	37,98	13,10
Kajeti	0	0	0	perennial	0	1563,4	1572,1	1566,8	527,7	0,32	33,29	6,91
Kajeti	0	0	0,9	perennial	0	1567,3	1597,3	1586,1	3650,7	0,00	53,26	9,42
Meni	8	5	0,3	perennial	16,67	1800,5	1820,1	1807,2	2421,3	0,02	54,39	13,96
Meni	8	5	0,3	perennial	16,67	1805,7	1812,0	1808,3	881,5	0,03	38,06	6,73
Meni	8	5	0,3	perennial	16,67	1806,8	1811,3	1809,2	316,2	0,08	31,04	10,38
Meni	8	5	0,3	perennial	16,67	1807,5	1813,8	1810,2	375,2	0,03	17,85	9,04
Meni	8	5	0,3	perennial	16,67	1808,1	1813,0	1810,1	467,7	0,04	31,08	8,66
Meni	8	5	0,3	perennial	16,67	1808,9	1812,8	1810,7	247,8	0,01	14,93	5,22
Meni	8	5	0,3	perennial	16,67	1809,2	1819,6	1813,4	1195,4	0,13	31,57	10,11
Sheki	0	0	0	perennial	0	1771,3	1778,2	1773,9	819,6	0,04	22,93	3,84
Sheki	0	0	0	perennial	0	1775,0	1889,4	1828,3	1329,9	0,08	32,55	10,97
Utal	0	0	0	perennial	0	2164,4	2270,9	2218,3	3722,6	0,01	34,58	7,03

Table 26: Tabular extract of rivers with particular exposure to non-point surface pollution

Name	Velocity	Width	Depth	River_flow	W_D_ratio	Z_Min	Z_Max	Z_Mean	Length [m]	Min_Slope	Max_Slope	Avg_Slope
Acho	0	0	0	perennial	0	1508,8	2017,4	1764,9	3474,7	0,0	40,3	15,4
Adiyo	0	0	0	perennial	0	2074,3	2169,5	2118,9	1397,5	0,1	33,4	8,5
Afalech	0	0	0	perennial	0	1930,1	1983,2	1954,5	2000,2	0,0	29,0	6,3
Barta	0	0	0	perennial	0	2010,4	2010,8	2010,6	84,2	0,1	2,5	0,9
Bubi	0	0	0	perennial	0	1276,8	1315,5	1294,9	1088,2	0,1	23,3	5,2
Bubi	0	0	0	perennial	0	1315,5	1342,4	1329,8	699,2	0,2	15,2	4,7
Bubi	0	0	0	perennial	0	1342,4	1366,2	1355,7	264,6	0,2	18,5	9,1
Buni	0	0	0	perennial	0	2438,0	2447,3	2442,4	436,4	0,4	23,9	9,1
Buni	0	0	0	perennial	0	2399,0	2439,3	2418,5	1615,5	0,0	29,7	6,0
Chita	0	0	0	perennial	0	1486,0	1638,0	1570,0	4578,6	0,0	43,4	9,9
Chita	0	0	0	perennial	0	1634,8	1712,7	1672,8	1926,0	0,1	25,3	9,0
Chita	0	0	0	perennial	0	1712,4	1839,6	1780,7	1401,4	0,0	27,0	10,6
Chita	0	0	0	perennial	0	1839,6	2022,0	1943,5	2934,2	0,0	43,8	10,2
Chorora	0	0	0	perennial	0	2208,2	2230,3	2220,4	779,7	0,0	23,9	6,9
Chorora	0	0	0	perennial	0	2200,1	2209,0	2204,1	341,9	0,0	14,4	5,2
Chorora	0	0	0	perennial	0	2194,5	2202,4	2199,6	998,6	0,0	23,6	5,8
Chorora	0	0	0	perennial	0	2194,0	2198,1	2196,3	90,1	2,1	19,7	9,1
Chuka	0,7	5	0,5	perennial	10	2052,1	2164,9	2117,1	1441,1	0,3	26,7	9,7
Chuka	0,7	5	0,5	perennial	10	2008,5	2053,0	2035,7	442,0	0,1	29,7	11,5
Chuka	0,7	5	0,5	perennial	10	1974,3	2008,5	1993,2	574,6	0,1	27,1	7,9
Chuka	0,7	5	0,5	perennial	10	1407,2	1421,6	1415,5	1455,2	0,0	29,4	6,6
Chuka	0,7	5	0,5	perennial	10	1485,9	1488,7	1486,9	237,8	0,0	11,5	3,5
Chuka	0,7	5	0,5	perennial	10	1399,2	1409,7	1406,2	477,9	0,2	19,9	6,2
Chuka	0,7	5	0,5	perennial	10	1417,5	1487,2	1441,5	2629,7	0,0	37,3	9,7
Chuka	0,7	5	0,5	perennial	10	1586,7	1657,0	1625,0	1732,5	0,0	45,3	8,2
Chuka	0,7	5	0,5	perennial	10	1353,0	1399,8	1378,5	1964,8	0,0	35,5	8,8
Chuka	0,7	5	0,5	perennial	10	1485,9	1531,4	1510,4	2366,8	0,0	30,2	7,9
Chuka	0,7	5	0,5	perennial	10	1528,5	1588,7	1564,0	2074,2	0,0	46,1	10,1
Dade	0	0	0	perennial	0	1851,6	1883,8	1872,6	1494,7	0,1	25,3	7,0

Dalga	0	0	0	perennial	0	2361,0	2372,2	2366,9	395,8	0,0	34,0	11,9
Dawiya	0	0	0	perennial	0	1508,6	1514,7	1512,5	84,6	2,3	32,2	12,8
Dipa	0	0	0	perennial	0	1497,5	1598,0	1549,3	639,7	0,0	39,2	17,1
Dokech	0	0	0	perennial	0	1312,6	1365,2	1340,6	1051,8	0,0	28,5	9,4
Duki	0	0	0	perennial	0	1526,5	1874,2	1725,8	3834,7	0,0	46,6	11,0
Gaja	0	0	0	perennial	0	1286,0	1294,8	1291,3	236,2	0,1	19,4	6,7
Gaja	0	0	0	perennial	0	2023,2	2113,7	2075,9	383,8	0,7	64,2	26,8
Galo	0	0	0	perennial	0	1379,8	1387,3	1383,9	202,8	0,1	14,1	6,0
Galo	0	0	0	perennial	0	1385,8	1412,6	1402,3	705,1	0,0	19,9	6,6
Galo	0	0	0	perennial	0	1374,5	1380,8	1376,7	148,0	0,0	20,7	4,8
Gata	0	0	0	perennial	0	1661,1	1852,4	1736,8	1623,5	0,2	57,4	13,8
Gata	0	0	0	perennial	0	1852,4	2092,4	1992,4	2619,3	0,0	56,4	10,9
Gati	0	0	0	perennial	0	1586,5	1613,8	1599,2	846,8	0,1	27,2	7,8
Gati	0	0	0	perennial	0	1661,2	1897,6	1760,9	2230,4	0,0	44,5	13,0
Gati	0	0	0	perennial	0	1612,9	1661,2	1641,8	1045,2	0,0	30,2	6,8
Gedi	0	0	0	perennial	0	1541,7	1600,2	1565,8	3195,2	0,0	36,2	7,5
Gemela	0	0	0	perennial	0	1805,6	1827,8	1821,4	1392,6	0,0	27,8	6,2
Geshi	0	0	0	perennial	0	1452,0	1453,8	1453,1	35,9	3,4	8,0	6,3
Gesho	0,5	0	0	perennial	0	2399,0	2407,7	2402,3	155,2	0,1	13,8	6,7
Gojeb	0,6	22	0,9	perennial	24	1307,8	1307,8	1307,8	938,5	0,0	0,0	0,0
Gozob	0	0	0	perennial	0	1555,9	1579,7	1568,2	1811,1	0,0	34,1	7,5
Gozob	0	0	0	perennial	0	1577,9	1625,3	1602,7	1746,1	0,0	25,2	5,0
Gugacha	0	0	0	perennial	0	1496,5	1954,8	1726,8	5797,0	0,0	40,2	11,5
Gugacha	0	0	0	perennial	0	1487,8	1499,1	1494,7	302,0	0,2	24,5	9,9
Gunji	0	0	0	perennial	0	1693,1	1714,3	1704,0	876,5	0,0	32,2	7,7
Haba	0	0	0	perennial	0	1631,5	1650,2	1640,5	369,6	0,4	15,6	6,8
Hahi	0	0	0	perennial	0	1528,5	1613,9	1573,1	1760,3	0,1	42,0	10,1
Hahi	0	0	0	perennial	0	1612,1	1919,7	1801,0	2793,2	0,0	69,1	13,4
Hahi	0	0	0	perennial	0	1918,0	2011,9	1973,7	648,4	0,2	52,2	15,8
Hana	0	0	0	perennial	0	1849,7	1854,6	1852,0	258,7	0,4	19,2	5,7
Hana	0	0	0	perennial	0	1857,4	1946,2	1919,6	2701,9	0,0	37,3	9,1
Hana	0	0	0	perennial	0	1854,5	1859,8	1857,4	394,9	0,0	15,1	6,2
Hana	0	0	0	perennial	0	1850,2	1861,0	1854,5	551,1	0,0	24,1	8,2
Hurhura	0	0	0	perennial	0	2322,6	2330,5	2325,3	184,6	0,0	42,2	13,6

Hurhura	0	0	0	perennial	0	2335,6	2372,6	2354,7	586,7	0,0	33,4	9,0
Hurhura	0	0	0	perennial	0	2329,2	2337,9	2333,5	254,1	0,2	25,2	7,7
Hurhura	0	0	0	perennial	0	2308,3	2327,5	2317,3	451,9	0,0	29,7	7,5
Hurhura	0	0	0	perennial	0	2308,3	2310,6	2309,1	125,4	0,0	19,4	5,2
Hurhurac	0	0	0	perennial	0	2305,9	2310,2	2308,8	156,3	0,0	20,4	5,5
Hurhurac	0	0	0	perennial	0	2304,2	2308,4	2305,9	307,6	0,2	21,0	6,8
Janja	0	0	0	perennial	0	1643,6	1840,5	1740,2	6247,9	0,0	54,5	8,0
Kishi	0	0	0	perennial	0	1539,6	1977,2	1802,3	4084,4	0,0	39,3	12,2
Kosha	0	0	0	perennial	0	1374,8	1968,2	1712,5	6677,5	0,0	47,7	11,0
Meni	8	5	0,3	perennial	17	1800,5	1820,1	1807,2	2421,3	0,0	54,4	14,0
Meni	8	5	0,3	perennial	17	1805,7	1812,0	1808,3	881,5	0,0	38,1	6,7
Meni	8	5	0,3	perennial	17	1806,8	1811,3	1809,2	316,2	0,1	31,0	10,4
Meni	8	5	0,3	perennial	17	1807,5	1813,8	1810,2	375,2	0,0	17,9	9,0
Meni	8	5	0,3	perennial	17	1808,1	1813,0	1810,1	467,7	0,0	31,1	8,7
Meri	0	0	0	perennial	0	1653,8	1677,2	1670,4	583,3	0,1	26,7	6,6
Meri	0	0	0	perennial	0	1654,0	1660,8	1657,6	408,7	0,9	22,5	6,5
Nekech	0	0	0	perennial	0	1759,6	1762,4	1761,5	49,1	0,2	20,6	7,5
Nekech	0	0	0	perennial	0	1776,7	1810,0	1790,4	368,3	0,0	31,3	10,9
Ofi	0	0	0	perennial	0	1966,8	2158,9	2076,9	1735,2	0,0	33,4	12,0
Ofi	0	0	0	perennial	0	1690,5	1966,8	1823,2	2279,8	0,1	39,7	13,5
Ofi	0	0	0	perennial	0	1678,8	1690,5	1683,0	86,4	5,3	26,6	13,9
Ofi	0	0	0	perennial	0	1654,3	1678,8	1664,1	365,1	0,1	25,4	9,7
Ofi	0	0	0	perennial	0	1374,7	1654,3	1523,1	3978,2	0,0	39,3	9,0
Shacho	0	0	0	perennial	0	2279,7	2306,7	2294,9	240,7	0,3	23,2	12,5
Shara	0	0	0	perennial	0	1613,4	2125,0	1802,3	3158,6	0,0	55,3	17,2
Shara	0	0	0	perennial	0	2123,7	2160,9	2143,8	820,7	0,0	38,0	8,3
Shato	0	0	0	perennial	0	1327,6	1426,0	1371,7	1742,8	0,0	31,7	8,4
Shato	0	0	0	perennial	0	1308,4	1331,7	1324,5	369,0	0,0	23,5	8,7
Shato	0	0	0	perennial	0	1307,8	1308,4	1308,1	118,2	0,0	5,6	1,9
Sheki	0	0	0	perennial	0	1771,3	1778,2	1773,9	819,6	0,0	22,9	3,8
Shengar	0	0	0	perennial	0	2175,0	2203,5	2185,7	328,3	0,0	21,0	10,7
Shuchi	0	0	0	perennial	0	1539,6	2109,2	1850,7	4686,5	0,0	39,6	13,3
Shuchi	0	0	0	perennial	0	1527,5	1539,6	1532,7	209,7	0,2	14,3	5,8
Shuka	0	0	0	perennial	0	2062,0	2108,6	2084,8	231,0	0,0	37,3	20,9

Shuka	0	0	0	perennial	0	1695,5	2063,7	1926,2	2855,7	0,1	64,2	15,3
Shuka	0	0	0	perennial	0	1641,8	1695,5	1676,0	639,4	0,1	30,1	13,5
Shuka	0	0	0	perennial	0	1419,8	1641,8	1532,1	2662,8	0,0	40,0	11,0
Shuri	0	0	0	perennial	0	1717,8	1865,9	1781,5	1717,3	0,0	40,2	12,0
Soto	0,7	0	0	perennial	0	2323,2	2328,9	2326,5	692,5	0,0	30,1	9,1
Soto	0,7	0	0	perennial	0	2325,0	2330,6	2327,0	1039,9	0,0	23,0	6,6
Soto	0	0	0	perennial	0	2325,9	2344,0	2338,3	1365,4	0,1	26,5	6,0
Taka	0	0	0	perennial	0	2399,5	2411,5	2406,1	847,4	0,0	22,4	6,7
Timkete Bahir	0	0	0	perennial	0	1401,0	1506,7	1467,8	1525,1	0,1	30,7	8,6
Timkete Bahir	0	0	0	perennial	0	1526,5	1654,7	1602,3	1499,6	0,0	25,2	9,2
Timkete Bahir	0	0	0	perennial	0	1502,6	1526,5	1515,6	519,8	0,4	21,5	7,5
Torech	0	0	0	perennial	0	2114,3	2158,9	2137,5	1005,8	0,0	30,6	8,7
Torech	0	0	0	perennial	0	1812,1	2114,3	1929,9	4087,6	0,0	53,8	9,4
v	0	0	0	perennial	0	2323,1	2329,6	2327,0	482,2	0,1	30,6	11,3
Waki	0	0	0	perennial	0	1853,4	1870,0	1863,9	438,2	0,1	36,6	11,3
Waki	0	0	0	perennial	0	1846,5	1855,7	1852,3	446,9	0,0	36,8	13,1
Yuchi	0	0	0	perennial	0	1816,2	1825,5	1821,0	676,0	0,1	10,6	2,8

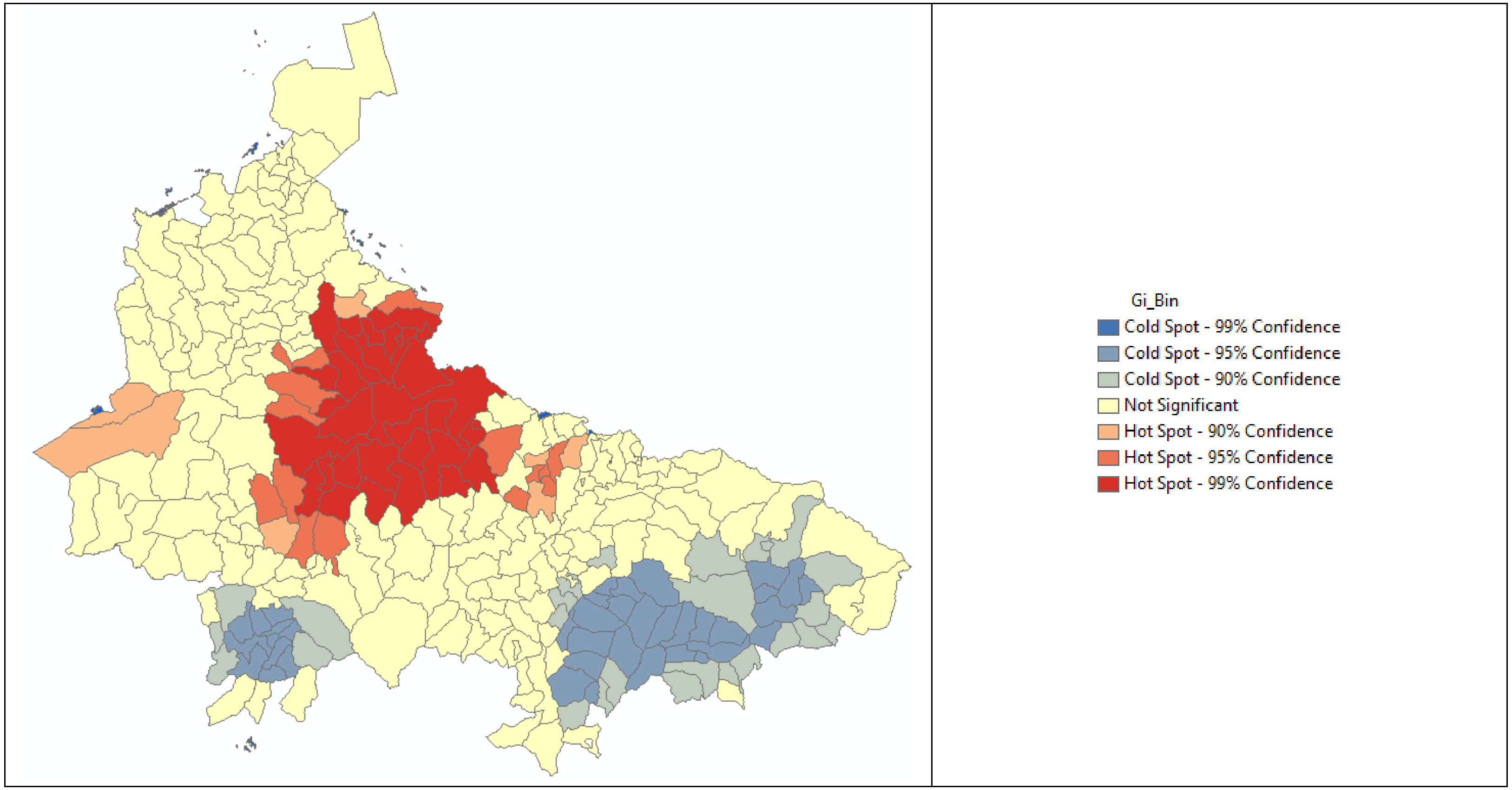


Figure 50: Hotspot analysis of wetland distribution within Kafa BR

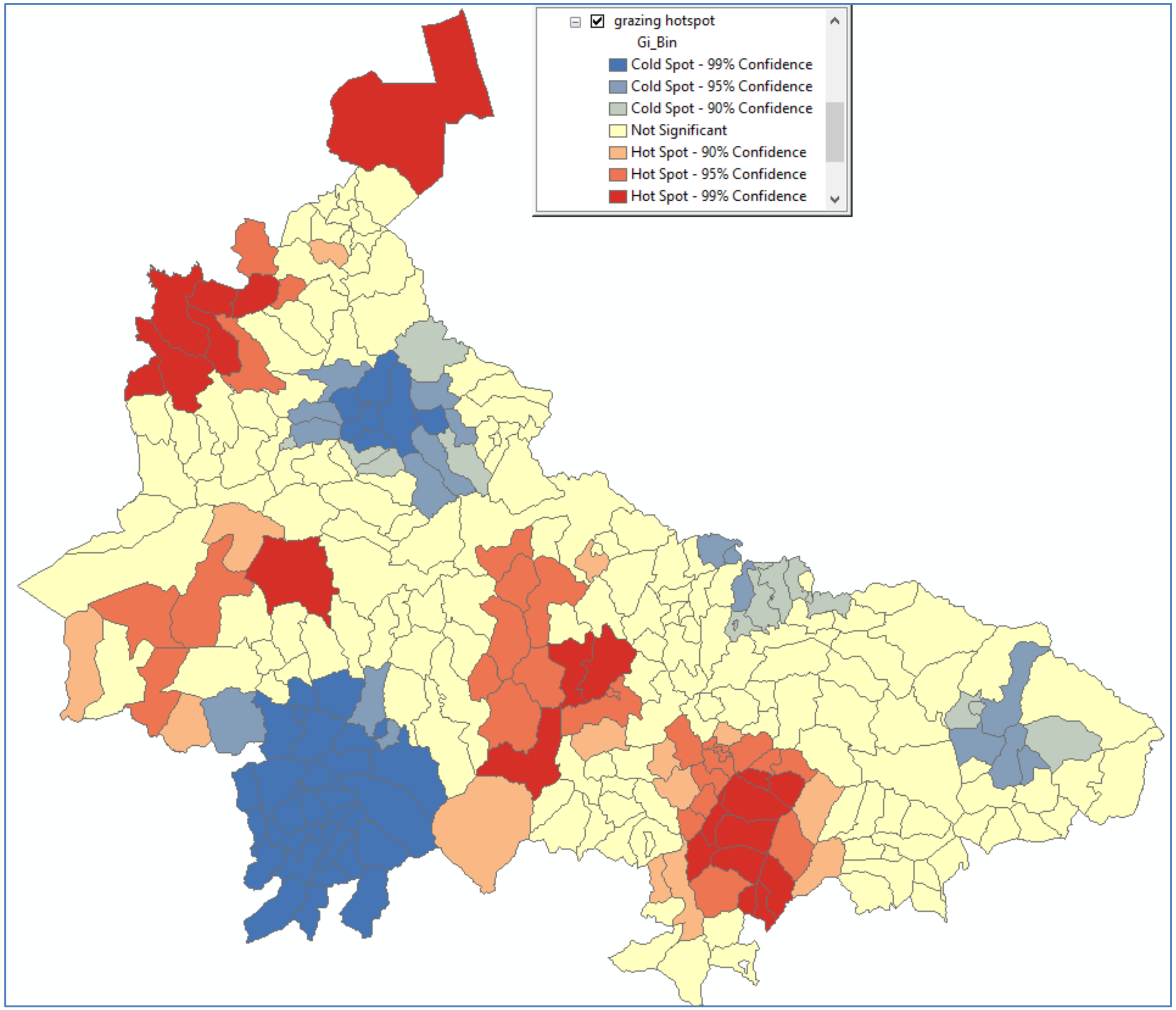


Figure 51: Hotspot analysis of alternative grazing areas within Kafa BR

Table 27: Slope classifiaction

Slope Class	Inclination
0 - 3°	Flat to gently undulating
4 - 7°	undulating
8 - 11°	Easy rolling
12 - 15°	rolling
16 - 20°	Strongly rolling
21 - 25°	Moderately steep
26 - 35°	steep
> 35°	Very steep

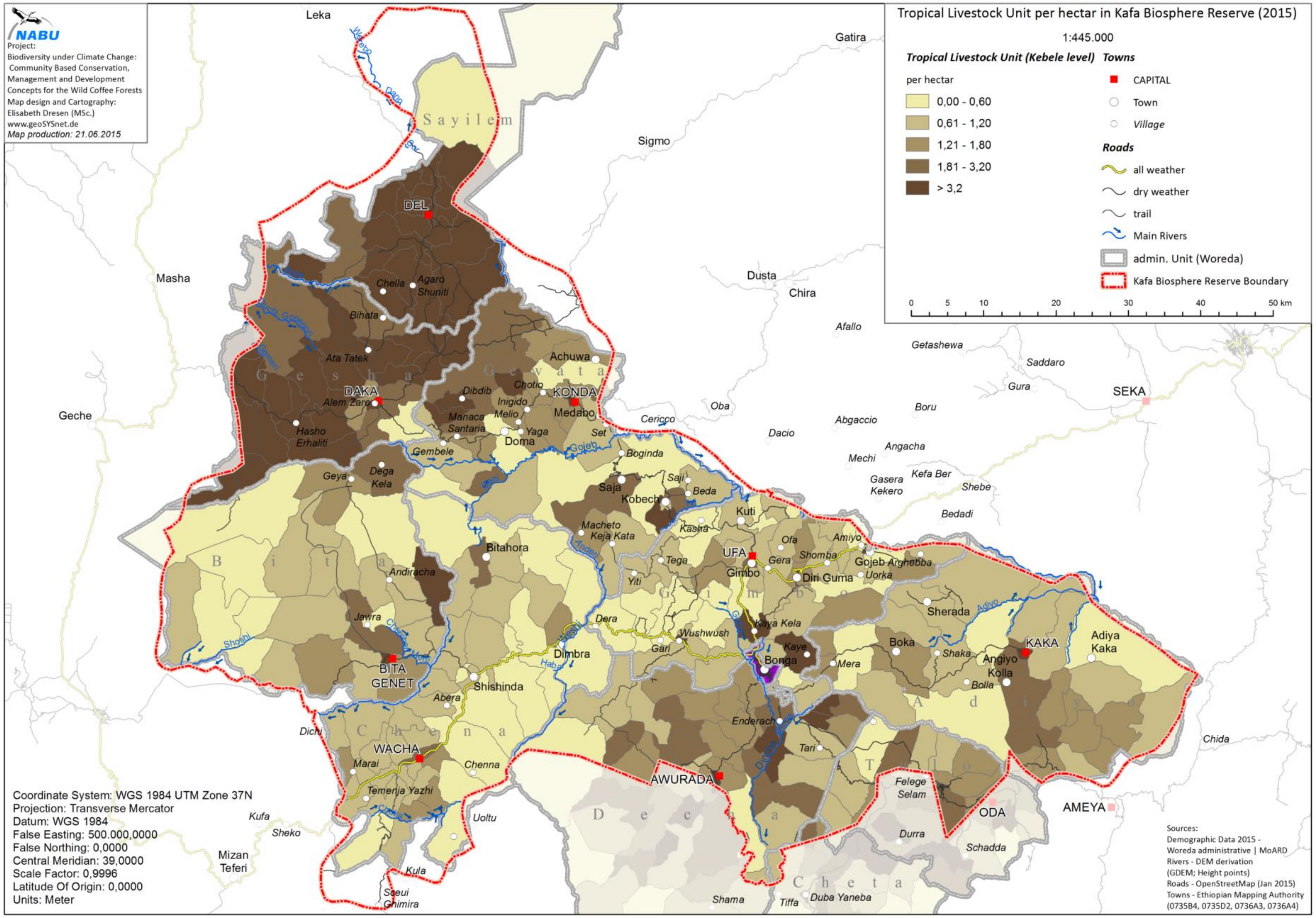
	Alemgono	Gojeb	Chidi
Contributing basin	Omo-Gibe	Omo-Gibe	Omo-Gibe
Altitude [m.asl]			
min. altitude	1642,02	1518,60	1809,64
max. altitude	1764,95	1634,21	1973,52
mean altitude	1709,89	1557,35	1887,91
height difference	122,93	115,61	163,88
Area [km^2] of contributing basin	618,38	1490,66	40,95
Area [km^2] of wetland	9,47	70,96	2,93
Wetland as proportion of catchment	1,53	4,76	7,15
Perimeter [km] of wetland	100,03	274,09	42,71
Area [km^2] of sub-basin	618,38	1490,66	40,95
Slope gradient average [°]	13,72	8,32	46,17
Morphometric Parameters			
Bifurcation Ratio	4,11	3,58	3,56
Total Stream length [km]	906,48	2275,62	59,76
Stream length Ratio	1,87	1,96	1,70
Drainage Texture:	1,05	1,05	1,05
Drainage Density:	1,47	1,46	1,46
Drainage pattern	dendritic	meanders and dendritic tributaries	dendritic
water flow direction	north - south	west - east	north - south
Hydrogeomophic assessment			
Water source	rainwater probably ground water	overbank flow, tributary inflow, ground	lateral/ overland inflow, rainwater
hydrodynamic	vertical fluctuation - sink system	unidirectional flow - throughflow system	unidirectional flow - source system
hydrogeomorphic class	depressional	riverine	organic soil flat

Table 28: Species list with relevant indicators

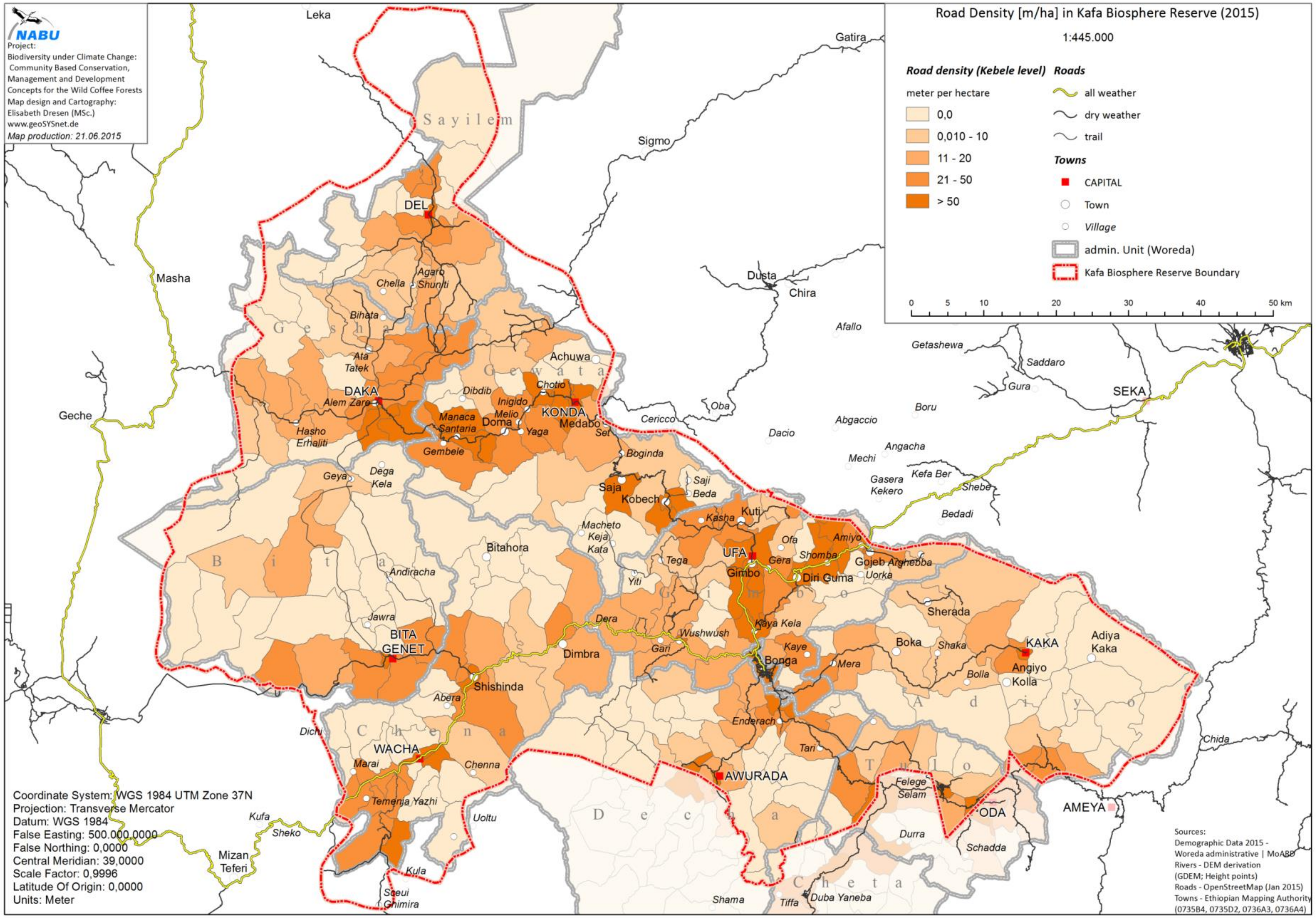
species	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Hygrophila schulli	Acanthaceae	moist depessions,marshy places					
Berula erecta	Apiaceae	mashy area	x			shallow water	
Centella asiatica	Apiaceae	damp grassland, swamp		x	x		
Gomphocarpus semilunatus	Apocynaceae	alluvial grassland		?	x	seasonally flooded	
Ageratum conyzoides	Asteraceae	woodland,fields,roadsides,garden		x	x		
Melanthera scandens	Asteraceae	swamp margins, river banks	x		?		
Impatiens ethiopica	**Balsaminaceae**	**river stream bank,swamps marshes, ditches, damp spots**					
Floscopa glomerata	**Commeliaceae**	**damp meadows, ditches, boggy grassland**		**x**	**x**		**grazing weed**
Cyperus denudatus	**Cyperaceae**	**swamps, swamp-edges, ditches, wet habitats**	**x**			**wet**	**peat formation**
Schoenoplectus corymbosus	**Cyperaceae**	**wet habitat,swamps,pools,lake margin**	**x**			**standing water**	**peat formation**
Cyperus latifolius	**Cyperaceae**	**swamp**	**x**			**wet ground**	**raw material, roof thatching**
Phyllanthus boehmii	**Euphorbiaceae**	**marshes, swampy grassland, wet banks**	**x**				
Vigna pakeri	**Fabaceae**	**grassland, woodland,forest margins, cultivations**		**x**	**x**		

species	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Plectrantus edulis	Lamiaceae	marshy areas or cultivated	x				grazing weed
Pycnostachys recurvata	Lamiaceae	marshy,moist ground	x				grazing weed
Urticularia stellaris	Lentibulariaceae	damp, shallow soil				submerged	
Dissotis canescens	Melastomataceae	seasonally water-logged grassland, wet flushes	x			water logged	
Dissotis cf. decumbens	Melastomataceae	stream margin in riverine forest					
Epilobium salignum	Onagaceae	marshed, swampy places	x				
Ludwigia abyssinica	Onagraceae	swampy ground, near rivers lakes	x				
Hyparrhenia dregeana	Poaceae	seasonally damp depressions, open grassland stony hilsides				seasonally moist/wet	grazing ?
Arundo donax	Poaceae	open wet soils by rivers,ditches				seasonally moist/wet	raw material, shelter, handicraft, grazing
Persicaria strigosa	Polygonaceae	marshy ground,swamps, lake shores, wet grassland					
Persicaria limbata	Polygonaceae	rivers, streams				in water	
Persicaria decipiens	Polygonaceae	roads, river banks					
Persicaria setosula	Polygonaceae	damp places				sometimes in water	
Alchemilla pedata	Rosaceae	moist groun, grassland	x				
Galium scioanum	Rubiaceae	damp wet swampy places					
Crepidorhopalon whytei	Scrophulariaceae	montane swamps	x				

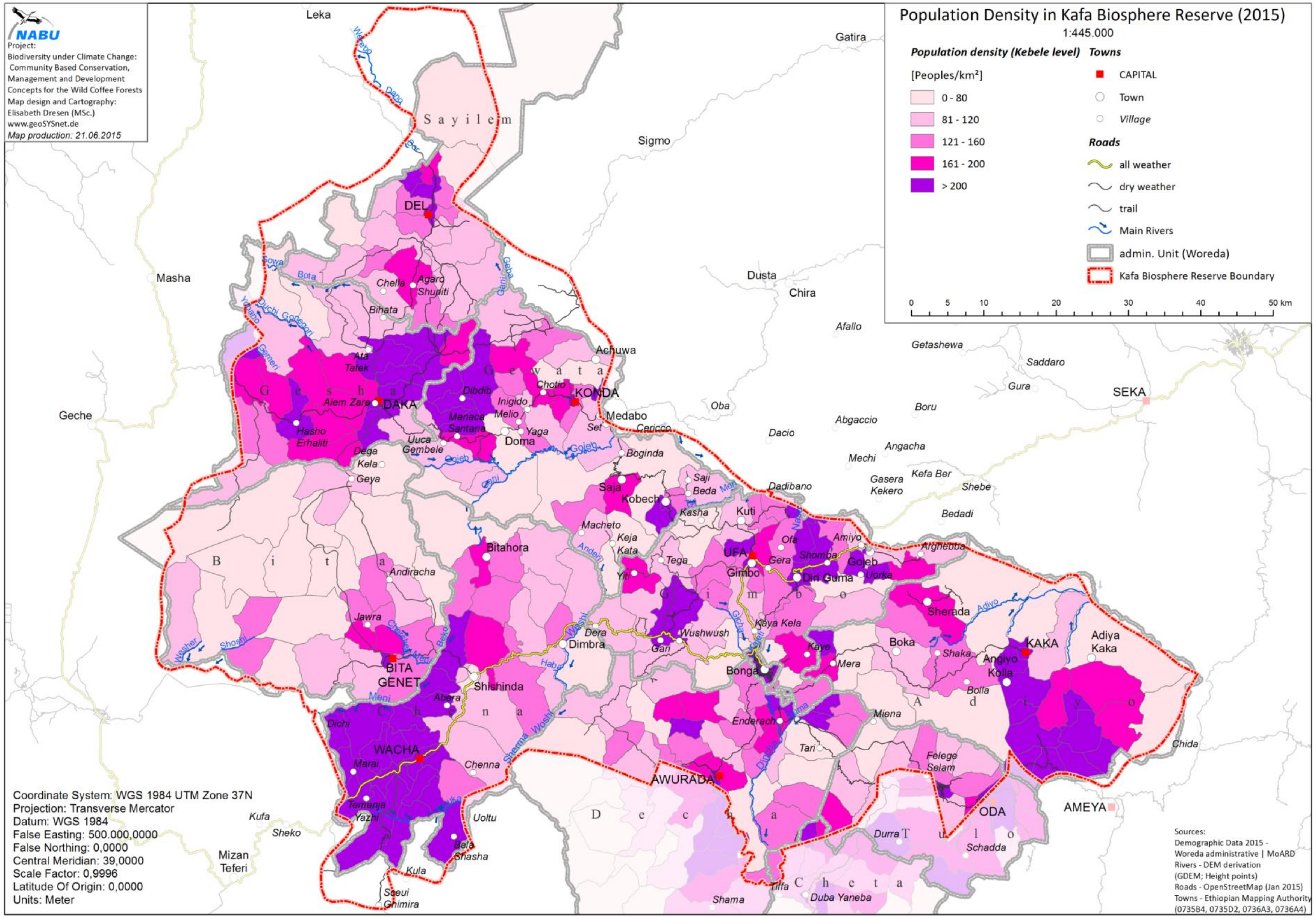
species	family	habitat	indicator				ecosystem service
			peatland	pasture	disturbance	hydrology	
Thelypteris confluens	Thelypteridaceae	swamps,floating bogs?	x			wet	peat formation
Triumfetta rhomboidea	Tiliaceae	iver ban, paths in forests, degraded bushland			x		



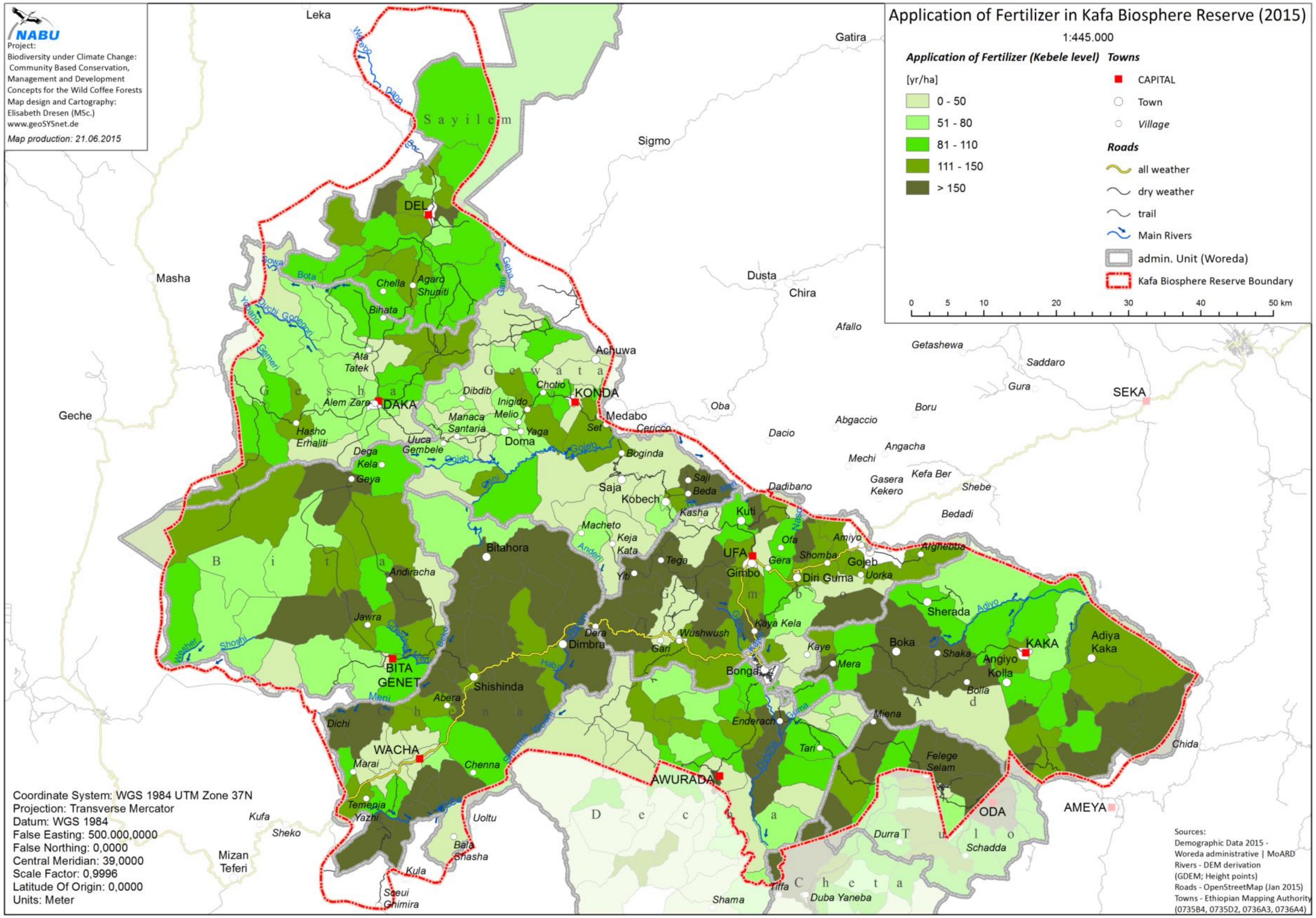
Map 27: Tropical Livestock Unit per hectare in Kafa BR



Map 28: Road Density [m/km] in Kafa BR



Map 29: Populataion Density in Kafa BR



Map 30: Application of Fertilizer in Kafa BR

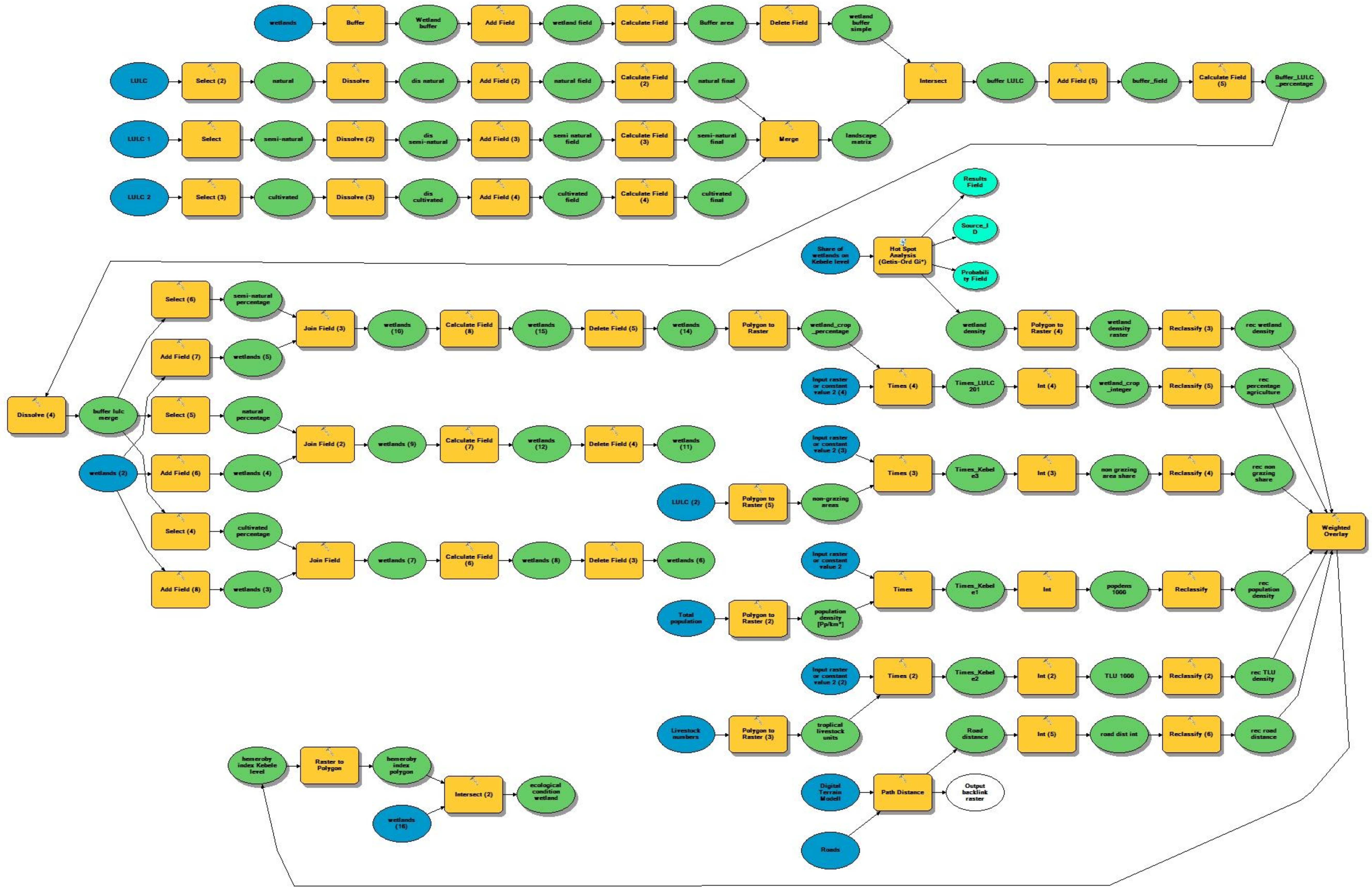


Figure 52: Spatial model to calculate the ecological condition of the wetlands in Kafa BR

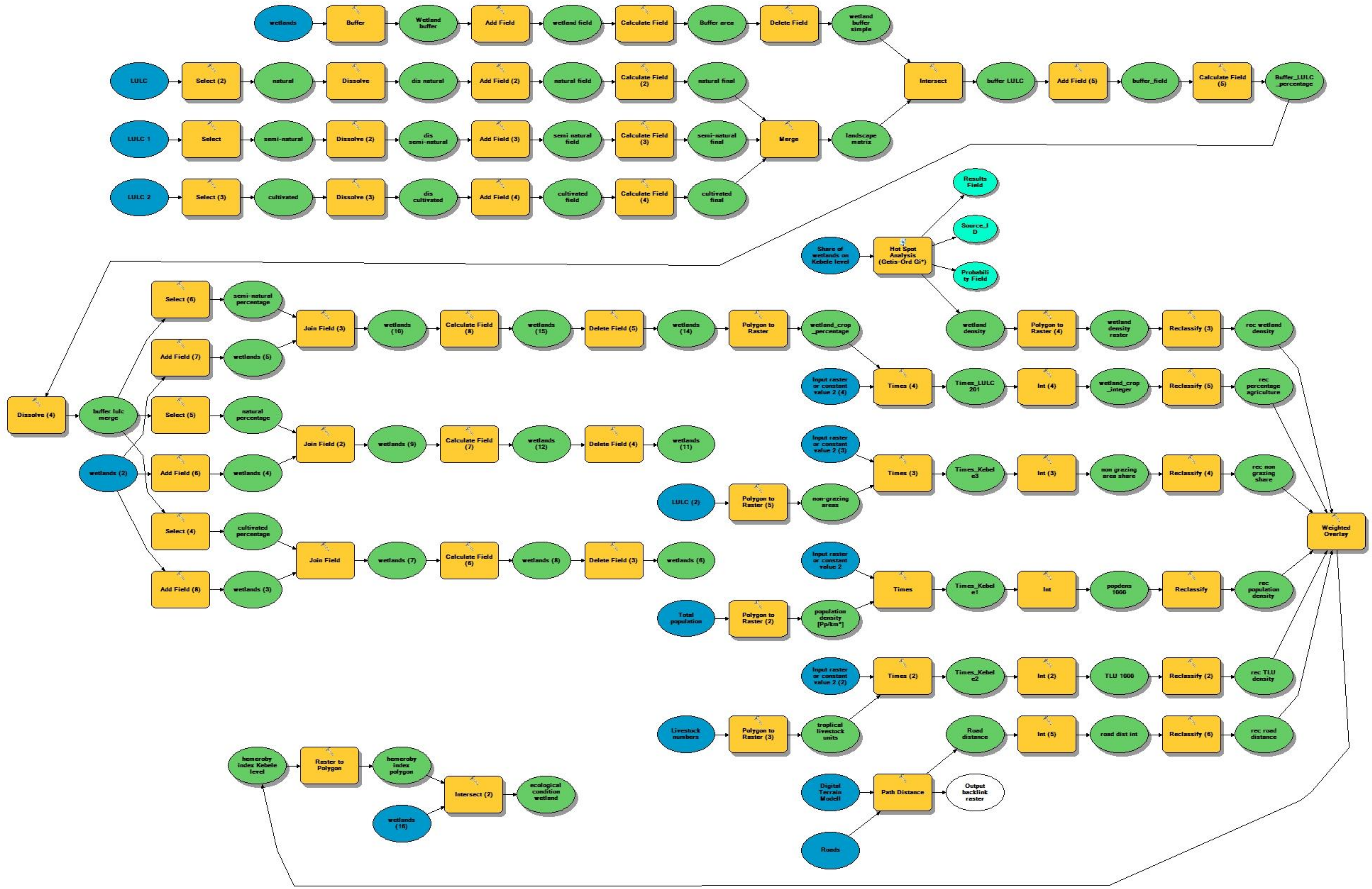


Figure 53: Spatial model to assess the direct threats to wetlands in Kafa BR

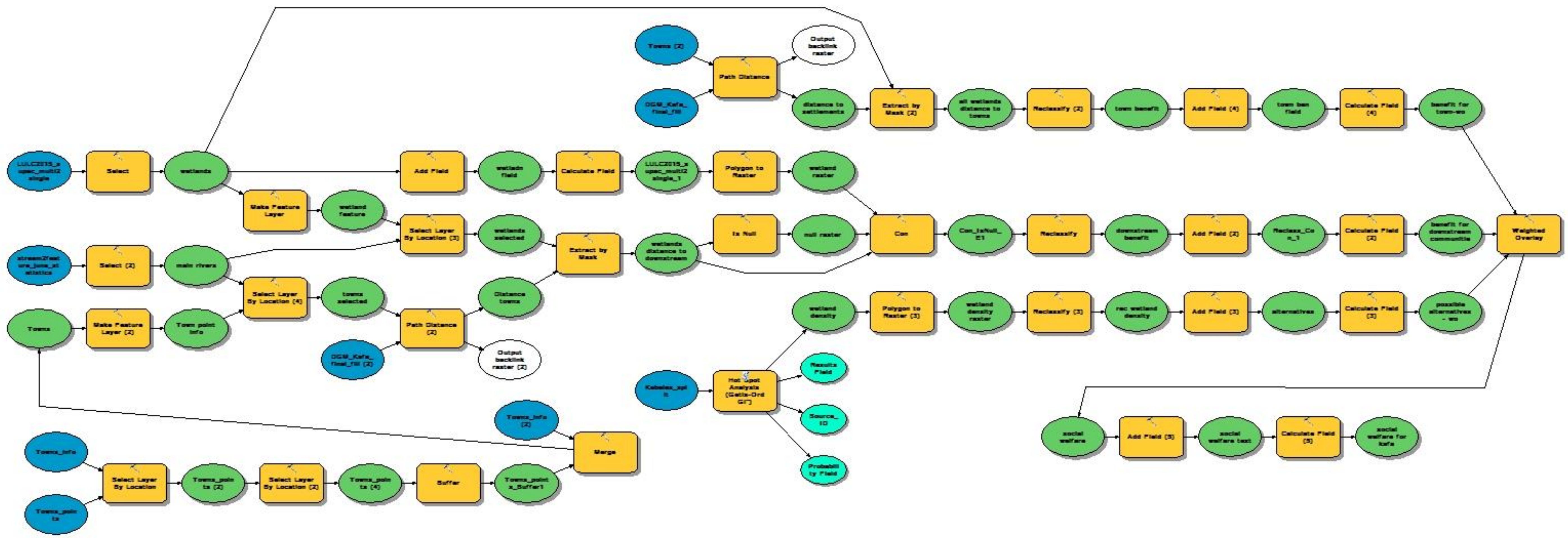
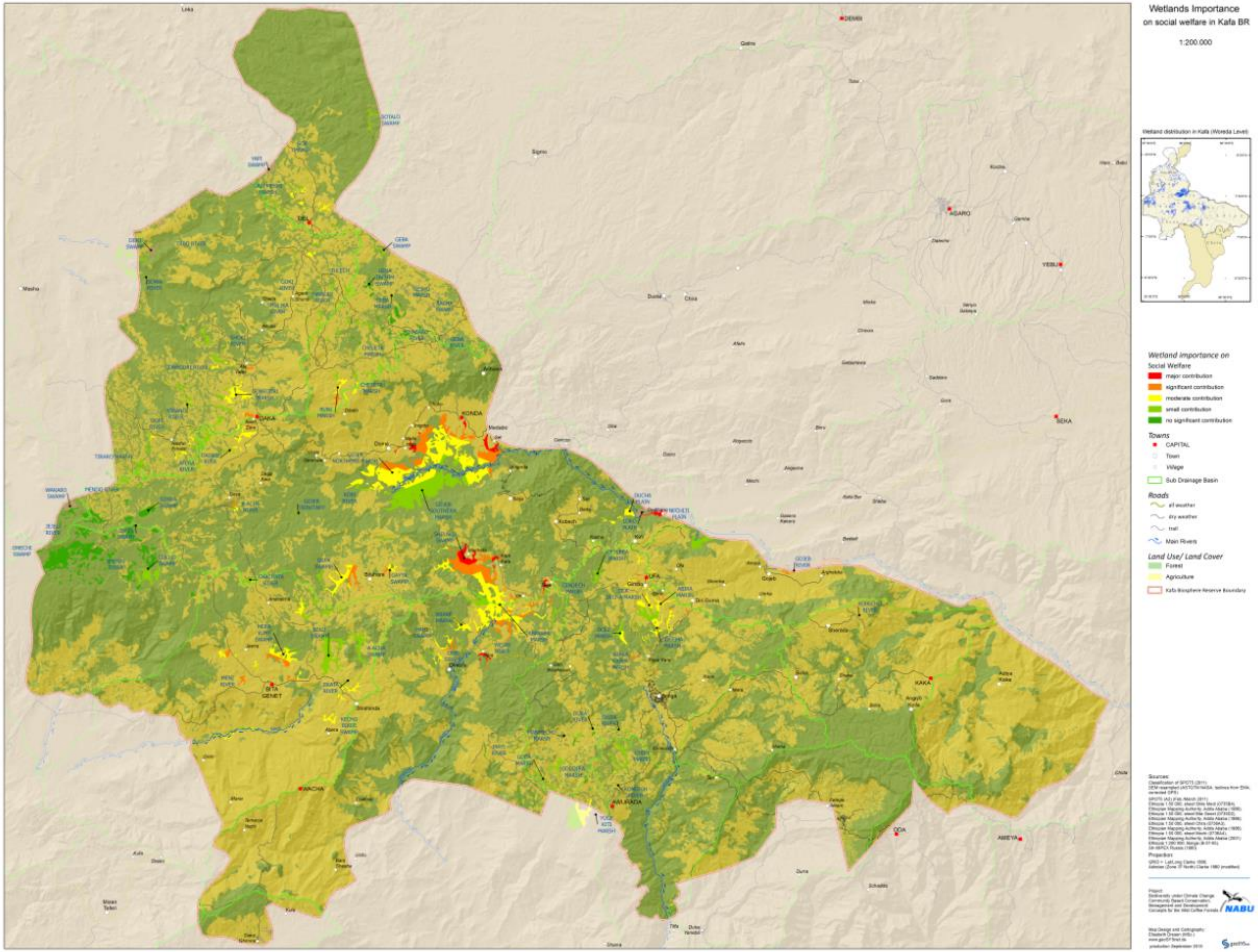
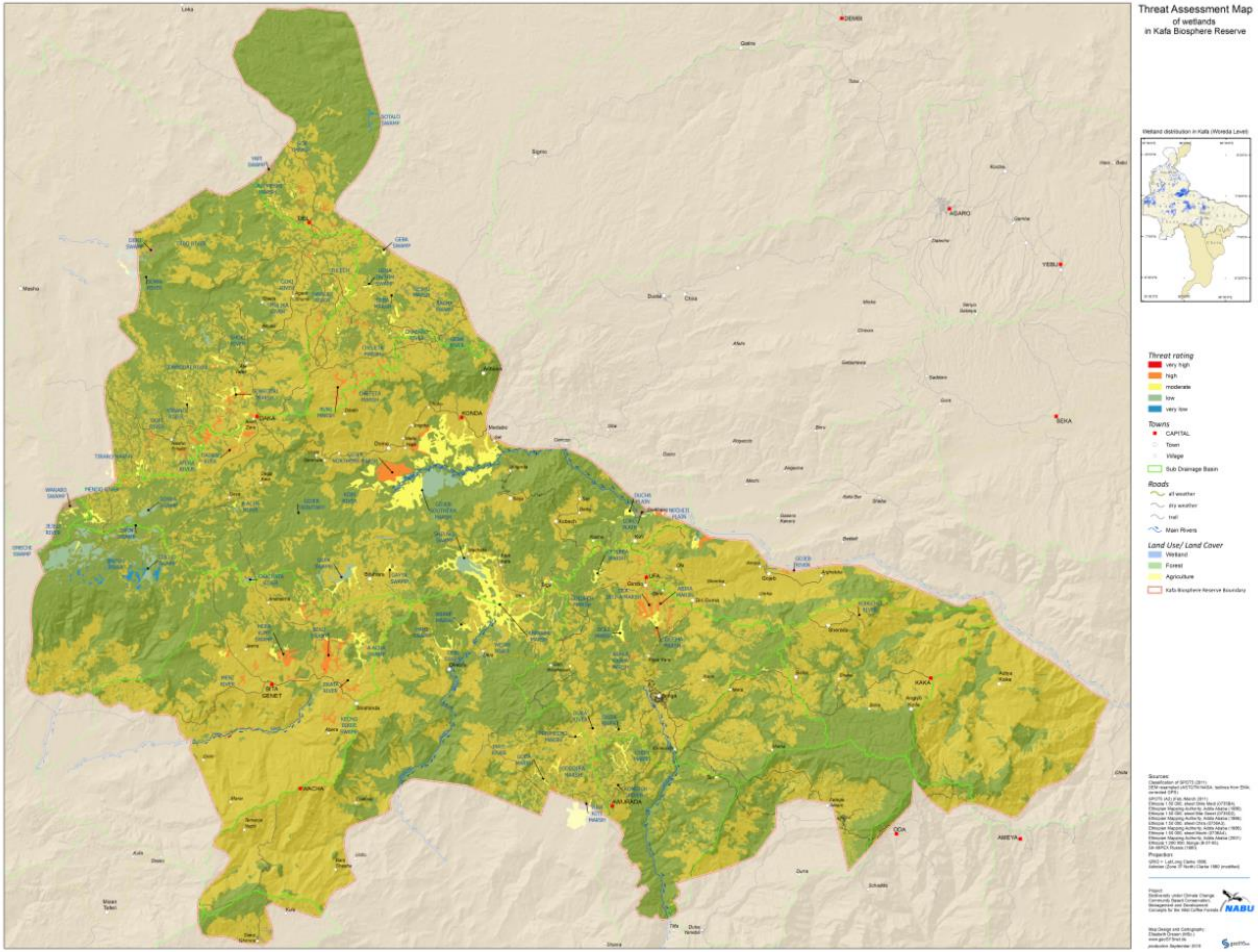


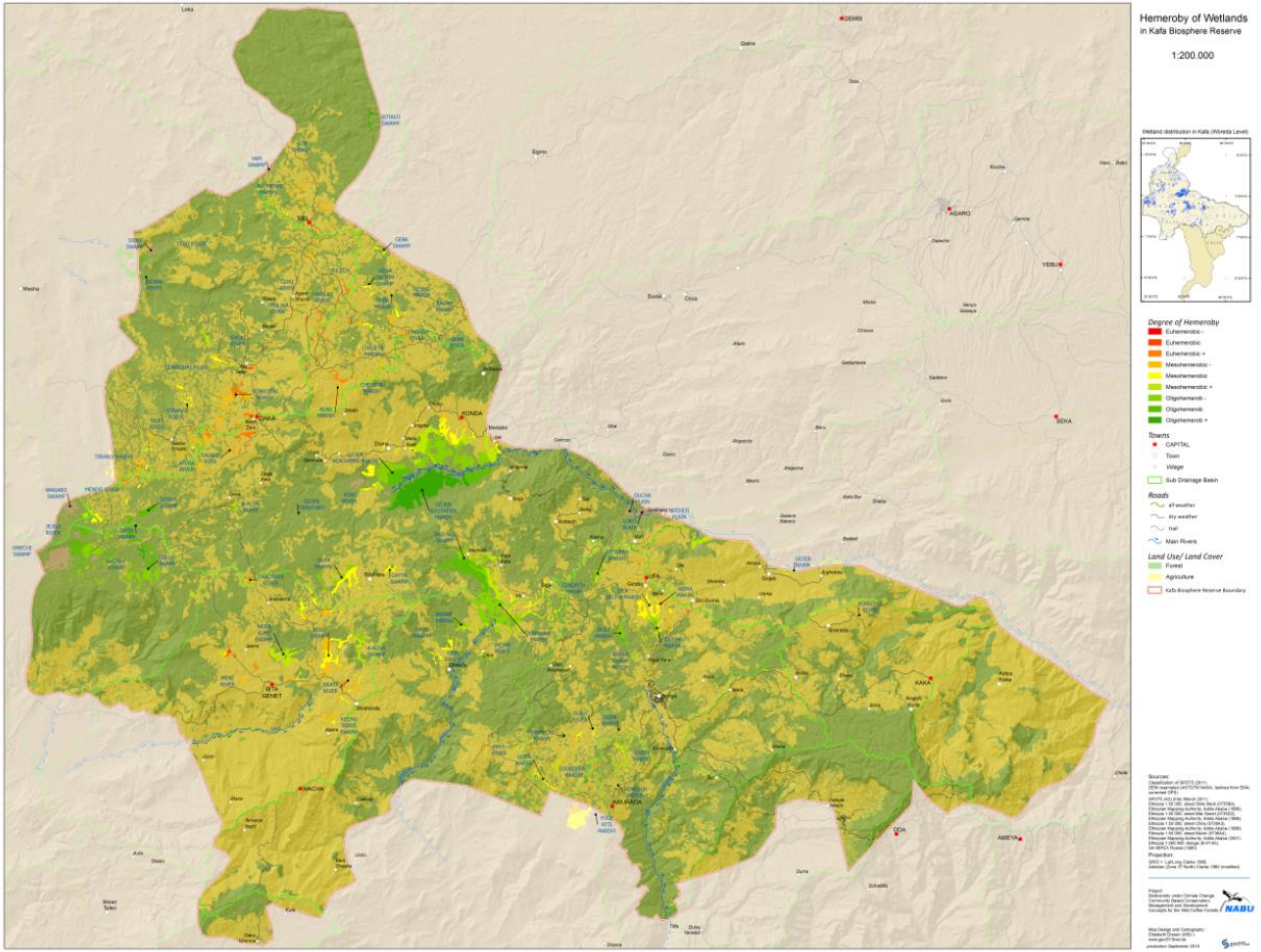
Figure 54: Spatial model to assess the wetland's contribution to social welfare in Kafa BR



Map 31: Wetlands Importance on social welfare in Kafa BR – PREVIEW



Map 32: Threat rating map for wetland ecosystems in Kafa BR - PREVIEW



Map 33: Degree of Hemeroby concerning wetland ecosystems in Kafa BR - PREVIEW