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Annys, Sofie; Adgo, Enyew; Ghebreyohannes, Tesfaalem; VAN PASSEL, Steven; Dessein, Joost & Nyssen, Jan (2019) Impacts of the hydropower-controlled Tana-Beles interbasin water transfer on downstream rural livelihoods (northwest Ethiopia). In: JOURNAL OF HYDROLOGY, 569, p. 436-448.

DOI: 10.1016/j.jhydrol.2018.12.012
Handle: http://hdl.handle.net/1942/28548

Impacts of the hydropower-controlled Tana-Beles interbasin water transfer on downstream rural livelihoods (northwest Ethiopia)

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ABSTRACT

Despite public awareness of unintended impacts (1980s) and well-developed international standards (2000s), downstream impacts of large hydropower projects still very often are not properly assessed. Impacts of (hydropower-regulated) interbasin water transfers (IBWTs) are considered self-evidently positive, although they can have far-reaching consequences for hydrogeomorphological systems and consequently river-dependent communities. In this study, the downstream direct and indirect impacts of the Ethiopian hydropower-regulated Tana-Beles IBWT are evaluated in an interdisciplinary way. The components of the framework of rural livelihoods are considered and changing contexts, resources' availabilities and livelihood strategies are analysed. Mixed methods are applied, combining hydrogeomorphological field observations, GIS analyses, scientific literature, policy documents, and semi-structured interviews with local people and local to federal authorities. Results show that the IBWT drastically increased the Beles river's discharge (with an average release of + 92 $m^3 s^{-1}$ at the outlet; *2 in rainy season and *12 in dry season 100 km downstream of the water release) and introduced dangerous situations for local communities (over 250 people drowned in the river). River bank erosion resulted in the uncompensated loss of farmland (163 ha) and the establishment of large-scale commercial farms increased the pressure on land and led to the impoverishment of displaced communities (4310 households). The project was implemented top-down, without any transparency, benefit sharing or compensation for external costs. This stresses the importance of downstream interdisciplinary impact assessments and highlights the need for decent in-depth ex post-analyses of hydropower projects. Environmental impact assessments should be taken seriously and cannot be considered a formality. In Ethiopia and in many developing countries, the hydropower industry is booming. Although dams and IBWTs *can be* the best solution for water-related problems in specific contexts, national development goals (such as the expansion of the electricity network) should not be at the expense of rural livelihoods.

KEYWORDS: hydroelectricity, clear water effect, river pattern adjustments, commercial farms, development induced displacement and resettlement, livelihood strategies.

1. INTRODUCTION

Over time, more than 50,000 large dams have been constructed (Berga et al., 2006) for a variety of purposes, ranging from electricity generation to flood control, water supply or irrigation development (Bergkamp et al., 2000). Despite rising international tensions over water allocations (Abdelhady et al., 2015) and increasing awareness of adverse and unintended impacts of hydropower projects (McCartney et al., 2000; WCD, 2000), a new dam building era has arrived in the 21st century. Considering the increasing demand for renewable energy and the world's unexplored hydropower potential, this new wave of dam building is likely to persist (Magilligan et al., 2016), although the political and institutional contexts for large-scale hydropower projects are remarkably different from those of the 1980s (Bazin et al., 2011). Simultaneously with the increasing number of dams, other supply-oriented hydraulic interventions, such as interbasin water transfers (IBWTs), increasingly also have been implemented in the past decades. Similar to dams, IBWTs aim to fix discrepancies in water resources' supply and demand and intend to induce economic development and enhance life quality (Gupta and van der Zaag, 2008). IBWTs are mainly implemented in countries with unequally distributed water resources (e.g. USA (Getches, 2005), China (Cai, 2008; Zhang, 2009), Brazil (de Andrade et al., 2011), Lesotho and South Africa (Davies et al., 1992), Australia (Young et al., 2004)) and have far-reaching impacts on the environment, altering the hydrological systems. This makes the implementation of IBWTs also subject of debate (Zhang et al., 2015).

Through time, hydropower projects have extensively altered landscapes, hydrological regimes, riverine ecosystems, agricultural production systems and rural livelihoods (Bazin et al., 2011). Rivers are transformed from 'flood-rivers' to 'reservoir-rivers' with regulated flows, decreased floodplain inundations and reduced active river beds (Graf, 2006); although the latter depend on the change in dominant channel forming discharge (i.e. bankfull discharge) (Brandt, 2000). IBWTs for hydropower development have similar downstream impacts as large dams that increase their dominant discharge (Brandt, 2000), although the amount of water transferred determines the 'severity' of consequences. Due to sediment trapping in reservoirs, river beds degrade and channels incise (Kondolf, 1997; Williams

& Wolman, 1984). This triggers river bank instabilities, bank erosion, channel pattern adjustments (Friedman et al., 1998; Michalkova et al., 2011), simplified channel morphologies (Brandt, 2000) and lowered floodplain water tables (Williams and Wolman, 1984). Increased (dominant) discharges with underloaded flows (sediment load < transport capacity) induce increased cross-sectional areas: in the short-term, channels widen through bank erosion or floodplain inundation and in the long-term, their beds degrade and incise (Church, 1995; Kellerhals et al., 1979). This directly impacts river-dependent communities, as water resources are critical to their economic development (McCartney et al., 2000). Due to year-round water availabilities, production systems often shift from rainfed or flood recession agriculture to irrigation agriculture, if sufficient technical support is given (Adams, 1985; Thomas and Adams, 1999). This can involve both economic losses and benefits for local communities (Garandeau et al., 2014), as benefits often are transferred to migrant labourers or investors (Bazin et al., 2011).

Up to 472 million people potentially have been affected downstream of large hydropower projects (Richter et al., 2010), which is far more than the 80 million people who have been displaced upstream (WCD, 2000). Despite the growing attention given to downstream impacts (e.g. Kibler et al., 2012), they largely remain understudied and most large-scale projects fail to account for their effects on river-dependent communities, up to hundreds of kilometres downstream of the hydropower stations (Bazin et al., 2011; Richter et al., 2010). For IBWTs, most projects do not consider the consequences for local communities in the 'downstream' areas, as the impacts are considered self-evidently positive, except for the ecological consequences (e.g. introduction of non-native biota, transmission of diseases, drastic alterations of riverine ecosystems… (Zhuang, 2016)). Most literature on IBWTs focuses on impacts in the areas of origin, as these areas are deprived of water resources and potentially of future developments (e.g. Bhattarai et al., 2005; Komakech et al., 2012). One of the main problems is that downstream impacts are difficult to quantify in monetary terms (e.g. ecosystem services), making environmental valuation necessary (Gupta and van der Zaag, 2008). Due to this market failure and externalisation of costs, hydropower projects may induce welfare losses for local communities (Bergkamp et al., 2000; McCartney et al., 2000). Another problem is that downstream impacts - if taken into account at all - very frequently are assessed from a single discipline perspective. However, in order to account as much as possible for inter-connected relationships between biophysics, socioeconomics and geopolitics, interdisciplinary approaches are required (Garandeau et al., 2014; Kibler et al., 2012; Sneddon et al., 2002).

So far, very few studies have considered the effects of hydropower-regulated IBWTs on 'recipient' socio-ecological systems. This study aims to contribute to this existing knowledge gap, and takes into account the 'downstream' impacts of the hydropower-controlled Tana-Beles IBWT in an interdisciplinary way. For this, the components of Scoones' (2009) framework of rural livelihoods are considered. This framework links the changing context and resources' availability (input) to changing livelihood strategies and outcomes (output). It allows to couple local level information with regional or national level information and allows to bridge natural and social sciences. In this regard, the specific objectives of the study are to analyse (i) how the downstream hydrogeomorphological and institutional contexts have changed, (ii) how this has affected the resources' availability and (iii) how the local river-dependent communities have responded to this fast-changing context. An additional specific objective (iv) is to evaluate the sincerity and use of the environmental impact assessment of the project. As the government has embarked on an ambitious dam building plan in view of creating a green economy, Ethiopia is the ideal country to study downstream impacts of hydropower projects. Although the hydroelectricity generation strongly contributes to economic growth, the social and environmental impacts of many hydropower projects have not been studied so far.

2. THE BELES RIVER AND THE BELES MULTIPURPOSE PROJECT

2.1 Demand for the Tana-Beles interbasin water transfer

Worldwide, most large-scale IBWTs currently occur between regions with 'water excess' and regions with water shortages (i.e. 'a substantial water deficit' - Cox, 1999), to meet increasing demands for urban and domestic water uses (e.g. de Andrade et al., 2011). However, this is not the case for the Tana-Beles IBWT: the Beles catchment (recipient area) is considerably water-rich with an annual rainfall of well over 1000 mm (NMA, 2016), has a relatively low population density and has long been considered peripheral, both in terms of topography/location and (economic) development (Markakis, 2011). Therefore, the demand for the Tana-Beles IBWT is somehow atypical. The potential of the Beles valley (large scale irrigation and hydropower development) first has been recognized in the early 20th century. In the 1960s, the water transfer formally has been suggested for the first time (Arsano, 2007), but it was in the 1980s that the Tana-Beles project was initiated in the context of severe droughts (contractor: Salini Impregilo). For several reasons, however, the tunnel was not constructed at that time (Nyssen et al., 2018; Wolde-Selassie, 2004). The 'current' Beles Multipurpose Project strongly roots in the former projects, but its rationale should also be seen in the context of the government's ambition to build a powerful hydropower network. With the Climate-Resilient Green Economy (CRGE) strategic plan, in which the Tana-Beles area has been identified as an economic growth corridor, the Ethiopian government aims to achieve a carbon-neutral middle-income status by 2025 (FDRE, 2011). At the same time, it aims to reach an installed hydropower capacity of 22,000 MW by 2030 (IHA, 2017) and has already invested a lot to reach this target: since 2009, the installed capacity has increased sevenfold - from 580 to 4054 MW - by connecting the Tekezze (300 MW), Beles (460 MW), Gibe II (420), FAN (97 MW), Gibe III (1 870 MW) and Genala Dawe (254 MW) projects to the national power grid. This makes Ethiopia the number one player in Africa concerning hydropower capacity (IHA, 2017; Verhoeven, 2011). However, the electric transmission lines are not yet able to transmit the total amount of producible energy.

2.2 Study area description and project details

The Beles river is an important tributary of the Blue Nile, located in the Amhara and Benishangul-Gumuz regions of northwest Ethiopia (Fig. 1). The Beles river emerges in the Tertiary trap basalts southwest of Lake Tana (around 1600 m a.s.l.) and drains strongly folded and faulted Precambrian rocks on its way towards the Blue Nile (Mège and Korme, 2004), which the river joins after 328 km at an elevation of 540 m a.s.l. In this study, the upper 96 river kilometers (RK) of the Beles river are considered (RK232 to RK328), which corresponds to a catchment area of 3050 km². Along these 96 RK, the river valley is confined (upper) to semi-confined (lower), with no or small to broader alluvial plains, delimiting the potentials for traditional irrigated agriculture. The area has a unimodal rainfall pattern, with rain from May to October, and receives on average 1000 to 1600 mm yr^{-1}. Average minimum and maximum annual temperatures are around 16°C and 33°C (NMA, 2016). Daily temperature contrasts are more pronounced than seasonal contrasts, and are strongest in the dry season. Dominant land cover types in this upper area are traditionally cultivated farmlands (33%), (dense) bushland (31%), degraded low-vegetated land (21%), grassland (5%), sugarcane monoculture (5%) and dense forest (3%) (own land cover classification, based on Sentinel-2 images, 2017). The main vegetation types are ‘Combretum-Terminalia woodland and savannah’ and ‘evergreen scrub’ (Friis et al., 2010). The area was initially inhabited by Gumuz people, but as a result of formal (forced) resettlement programmes and spontaneous migration of Amhara, Agaw and other population groups, the Gumuz were ‘pushed’ towards the less accessible yet fertile lowlands (James, 1986; Wolde-Selassie, 2004).

Since May 2010, the Beles catchment (13,571 km^2) is connected with the Tana catchment (15,080 km^2) by an underground IBWT from Lake Tana to the Beles valley (Fig. 1), constructed by Salini Impregilo, a global player in large, complex infrastructure projects (www.salini-impregilo.com), with a longstanding and controversial history of hydropower projects in Ethiopia (e.g. NCP Italy, 2017), including in this study area (Fedeler, 2018; Wolde-Selassie, 2004)(Section 2.1). Starting from the tunnel inlet (located at 11°53’N, 37°01’E), the lake water is transferred through a 12-km headrace tunnel towards a vertical penstock, delivering water to the four hydro turbines for electricity generation (460 MW), using a hydraulic head of 314 m. From the powerhouse, the water is conveyed via a 7-km long tailrace tunnel towards the Juhana river, an upstream tributary of the Beles river (EEPCo, 2011; SMEC, 2008). Five kilometers downstream of the hydropower outlet, the Juhana river joins the main Beles river. The Beles river receives up to 70% of the water outflow of Lake Tana, while the remaining 30% (instead of 100% before 2010) still flows towards the Blue Nile. Since 1996, the Chara-Chara weir has regulated the outflow to the Blue Nile – Lake Tana is operated as a reservoir – and consequently, more recently, also indirectly to the Beles river (SMEC, 2008). If lake levels are high, the Chara-Chara weir spills over and releases an unregulated flow to the Blue Nile (about 110 days yr^{-1}; Interview of EEP officer). This makes the proportion of water allocated to both rivers variable trough time. A fixed release of 17 m³ s^{-1} to the Blue Nile outlet has been proposed, with an absolute minimum of 10 m³ s^{-1} (Alemayehu et al., 2010). The Tana-Beles IBWT has a design discharge of 77 m³ s^{-1} on average and 160 m³ s^{-1} maximum. To dissipate energy of the newly obtained high flows, three weirs have been constructed in the five kilometers downstream of the outlet (EEPCo, 2011; Fig. 1). In view of the artificial high discharges, we refer to the 'Beles river' as the lower 5 km of the Juhana river plus the 'original' Beles river starting from the point of junction (Fig. 1 – inset map).

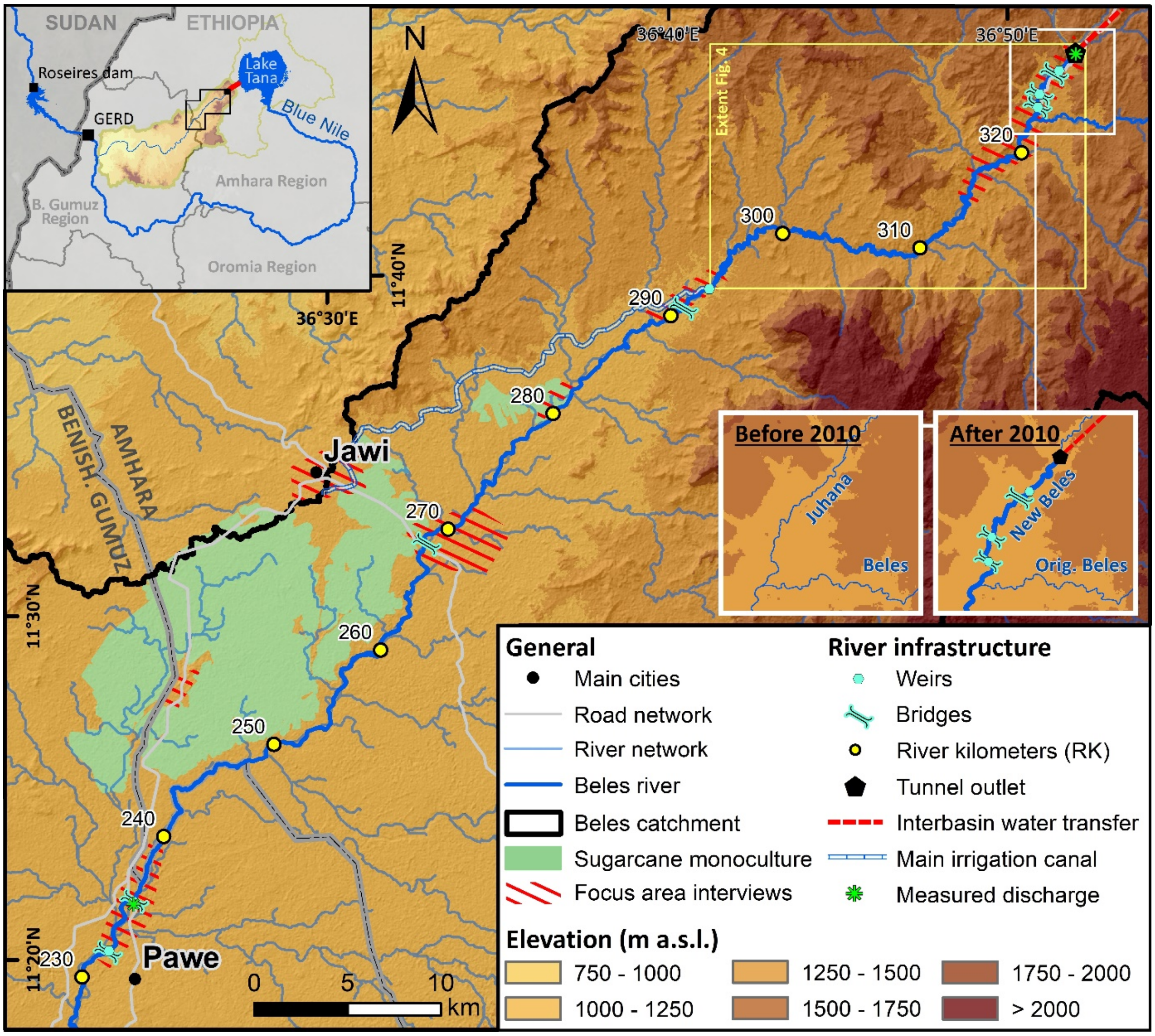

Fig. 1 Study area location.

3. METHODS AND MATERIALS

3.1 IBWT-induced impacts on hydrological and hydrogeomorphological context

As hydrological regimes strongly impact river-dependent communities and their livelihoods, it is important to clearly understand how the downstream hydrological and hydrogeomorphological contexts have changed after the implementation of the IBWT.

First, the changes to the river's discharge were studied based on the available data from the Ministry of Water, Irrigation and Electricity (MoWIE) and the Ethiopian Electric Power Corporation (EEPCo). Average daily discharge data for the station in Pawe (RK 232) were available from 1990 to 2011 (MoWIE, 1990 - 2011), and for the hydropower station (RK 328) from May 2010 up to October 2017 (EEPCo, 2010 - 2017). The latter consist of discharges that are estimated based on the daily energy production and a project-specific conversion factor (hydrological detailed information is presented as Online Supplementary Data). As no records were available for intermediate locations, for the hydropower outlet before 2010 or for Pawe after 2011, the drainage area ratio method (Archfield and Vogel, 2010) was applied to estimate average discharges and expand the available discharge data set.

Second, as no continuous records on suspended sediment load were available, we directly focused on the induced second-order changes (Brandt, 2000); the cross-sectional and planform changes were considered. To study the planform changes in a space-time framework, the active river bed (RK328 to RK293) was mapped for the years 1984 and 2017, using aerial photographs (APs) at a nominal scale of 1:50 000 (EMA, January 1984) and high-resolution satellite images (HRSIs) (DigitalGlobe, February 2017). Field observations and the geo-information system 'Planet Explorer' (including summer season cloud free HRSIs; www.planet.com; Taukenov et al., 2018) were additionally used to map the extent of the 2017 active river bed in detail. The APs of 1984 provide the most extensive cover of the 'pre-IBWT river' and it was assumed that the Beles river had reached an equilibrium state before 1984 (sensu Brandt, 2000) and consequently (almost) did not change up to 2010. This assumption was verified for segments RK312 to RK303 in 2002 and RK297 to RK293 in 2005, using available 'historical' HRSIs in Google Earth (DigitalGlobe). Pre-processing of the set of seven 1984 APs consisted of (i) optimizing the image contrast and brightness in Adobe Photoshop, (ii) orthomosaicking the photographs in Agisoft PhotoScan Pro using the integrated semi-automatic SfM-MVS algorithm (Verhoeven et al., 2013) and (iii) georeferencing the clipped ortho-mosaic (1.5 km-buffer along river) in WGS84 in ArcMap 10.4 using 40 ground control points (0.48 points per km², RMSE of 4.49 m). DigitalGlobe HRSIs of the years 2011 (RK328 to RK321, RK300 to RK293) and 2013 (RK328 to RK313) allowed to locally map intermediate changes after the IBWT became operational. For each river segment (delineated by the RKs), the following measures were calculated and compared over time: average width (m), length of centerline (m) and area (ha) (Michalkova et al., 2011). The sinuosity (P_T) and braiding index (BI) of the considered river stretch were calculated as follows:

$P_T = \frac{L_{CMAX}}{L_R}$; L_{CMAX} = length of channel centerline, L_R = reach length (thalweg) (Friend and Sinha, 1993)

$BI = 2\sum \frac{L_B}{L_R} + \sum \frac{N_B}{L_R}$; L_B = bar length, L_R = reach length (thalweg), N_B = number of bars (Germanoski and Schumm, 1993)

In January and October 2017, extensive field visits were done in the study area and observations of channel incision were made based on the presence of undermined bridges (Kondolf, 1997) and ancient river courses well above the current course of the Beles river. The latter were identified in the field by the presence of rounded pebbles and sprouting/young vegetation, and were dated by interviews and DigitalGlobe HRSIs (Google Earth).

3.2 IBWT-induced impacts on socioeconomic and institutional context

Local socioeconomic and institutional contexts are expected to change drastically due to the hydrological changes induced by the IBWT. It is expected that many new players will enter the development arena (Olivier de Sardan, 2005) (e.g. private investors, governmental and non-governmental organizations…) as the permanent water availability makes the area suitable for (large-scale commercial) irrigated agriculture. To study how the socioeconomic and institutional contexts have changed exactly after the implementation of the IBWT, existing scientific literature and policy reports regarding developments in the upper Beles basin were consulted. During the field visits in 2017, municipal and district chairmen were interviewed to obtain additional information on ongoing and planned large-scale interventions. The Beles integrated sugarcane development project office, the EEP head office, ESC head office and MoWIE - EIA & Social Development Office in Addis Ababa were visited to interview civil servants on the implementation of the Beles multipurpose project and related institutional changes (Table 1). Summaries of the interviews were transcribed and were encoded using NVivo 11 software for processing.

Table 1 Location, category and number of semi-structured interviews used to study IBWT-induced contextual changes and changes in livelihoods strategies

Location	Category of interviewees	n
Upper Beles (Alefa and Achefer districts)	Local authorities: municipal and district chairmen	10
	Farmers	21
	Farmers to be displaced	31
Jawi district	Local authorities: municipal and district chairmen	3
	Displaced farmers	45
Pawe district	Local authorities: municipal and district chairmen	2
	Displaced farmers	17
	Smallholder irrigation farmers	17
Bahir Dar	Regional authorities: Abay Basin Authority, Bureau of Water, Land Administration	3
Addis Ababa	Federal authorities: MoWIE, EEPCo, ESC	8

3.3 IBWT-induced impacts on livelihood strategies

To study how local communities have responded to IBWT-induced contextual changes, we investigated how the (livelihood) resource availability has changed over time and how this changing availability has impacted livelihood strategies. Based on Scoones' (2009) framework of rural livelihoods, the impacts on natural, human, social, economic and physical capital were examined (with a main focus on natural capital) and their implications for the different livelihood strategies (i.e. intensification, extensification, diversification and migration) were assessed. For this, semi-structured interviews with local people and local authorities were conducted (Table 1). Respondents spatially distributed along the Beles river were consulted (Fig. 1), until the point of data saturation was reached for a certain sub-area. However, some parts of the study area were inaccessible due to the mountainous character of the terrain, the high vegetation density and the lack of access roads. The focus during the interviews was on how local communities have experienced the implementation of the IBWT, how the IBWT has changed daily life practices and whether it has been a positive evolution for the area. Another focus was on why some people make a shift towards another livelihood strategy and others do not. The resources required to make a particular shift were identified.

4. RESULTS

4.1 First-order changes of the fluvial system: water and sediment flow

The discharge of the Beles river has tremendously increased due to the IBWT (Fig. 2). Since 2010, an average of $2.81*10^9$ m³ water has yearly entered the Beles basin. This corresponds to an additional average discharge of 92 $m^3 s^{-1}$ at the hydropower outlet, which is well above the planned design discharge of 77 $m^3 s^{-1}$ (SMEC, 2008). Through time, the average water transfer has increased steadily, with a peak in 2015, when the average daily discharge exceeded 120 $m^3 s^{-1}$ almost 230 days (Fig. 2a). Although it was anticipated that the peak discharges of the hydropower outlet would coincide with natural peak discharges (SMEC, 2008), this is not the case. Over time, the average monthly discharges at the hydropower outlet have been the highest during the dry season, in the months of February to April (Fig. 2b). While the average discharges for the rainy season months (May to October) increased with factor 32 at the hydropower outlet, the average discharges for the dry season months (November to April) increased well over a hundredfold. Downstream, the proportional impact decreases strongly with distance, but remains considerably high for the first 100 km. At RK293 (upstream of the main irrigation canal intake), discharges in the rainy season increased fourfold and increased with factor 45 for the dry season months. At RK293, about 10 $m^3 s^{-1}$ water is diverted from the river to irrigate the sugarcane plantation in the dry season (interview of ESC officer). Due to clogging of the main canal, however, irrigation water has not been permanently used over time. In Pawe (RK232), the discharges almost doubled for the rainy season and increased with factor 12 for the dry season (Fig. 2c-d). In addition to strong increases in average daily to seasonal discharges, the diurnal pattern of the river flow has changed as well (Fig. 3). In correspondence with the electricity demand, discharges vary strongly throughout the day, with peaks in the morning and evening near the hydropower outlet. Every time an additional turbine is brought online, a flood wave travels down the river.

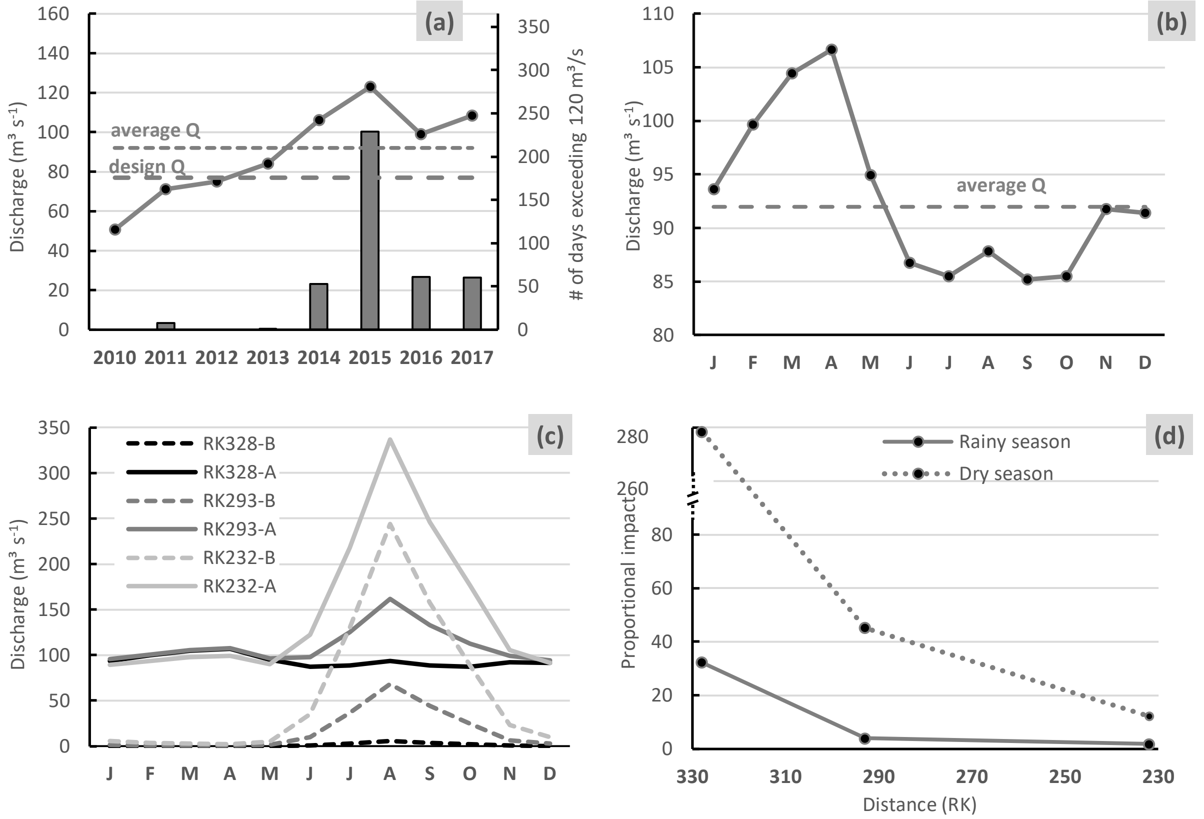

Fig. 2 Discharge characteristics of the Beles river after IBWT: (a) Average yearly discharge at RK328 (hydropower outlet) (solid line) and number of days exceeding 120 m³ s^{-1} (stack bars); (b) Average monthly discharge at RK328; (c) Average monthly discharge before (-B) and after (-A) IBWT implementation at RK328, RK293 (upstream of main irrigation canal intake) and RK232 (Pawe); (d) Proportional increase in seasonal average discharges at RK328, RK293 and RK232. Data sources: MoWIE (1990 - 2011), EEPCo (2010 - 2017), drainage area ratio method (Archfield and Vogel, 2010).

Fig. 3 High diurnal variability in river discharge at RK268 (Jawi bridge): photos taken at 1 PM (left) and 3 PM (right), on 23 January 2017 (Details in supplementary data Fig. F).

At different points along the river (but mainly in the upper reaches), clear observations of river incision were made during the two field campaigns. The bridges near Jawi and Pawe are undermined and in the upper basin, close to the IBWT outlet, abandoned river channels were found well above the current position of the Beles river. At RK323, for example, the old river bed is located more than two meters above the current average water level, and thus even higher above the current river bed. Local farmers explained that the river had shifted its position about two months after the IBWT became operational, and started incising afterwards.

4.2 Second-order changes of the fluvial system: planform configuration

In addition to observations of river incision, many observations of lateral erosion were made, which can be attributed to the clear water effect and increase in discharge (Brandt, 2000). As it has important impacts for local farmers, the extent of the lateral erosion was quantified by mapping the planform changes for segments RK328 to RK293. The active river bed was mapped for the years 1984 and 2017. Based on the overlay of both maps, planform changes were visualized (Fig. 4) and quantified. Between 1984 and 2017, 90.6 ha continuously was active river bed (grey), 25.6 ha was abandoned by the river (green) and 141.2 (red) ha of land was taken by the river (162.7 ha if we include intermediate changes, red + yellow). The total area of active river bed almost doubled, from 124 ha to 240 ha (+94%), and the average width of the river increased from 29.3 m to 66.5 m (+127%). The length of the centerline of the river declined from 38.8 km in 1984 to 35.5 km in 2017 (-8.5%). Accordingly, the sinuosity of the river decreased from 1.34 to 1.23 (river straightening). The strong confinement constrains the river to become completely straight (sinuosity < 1.1). Locally, the river adopted a braided river pattern (Fig. 5).

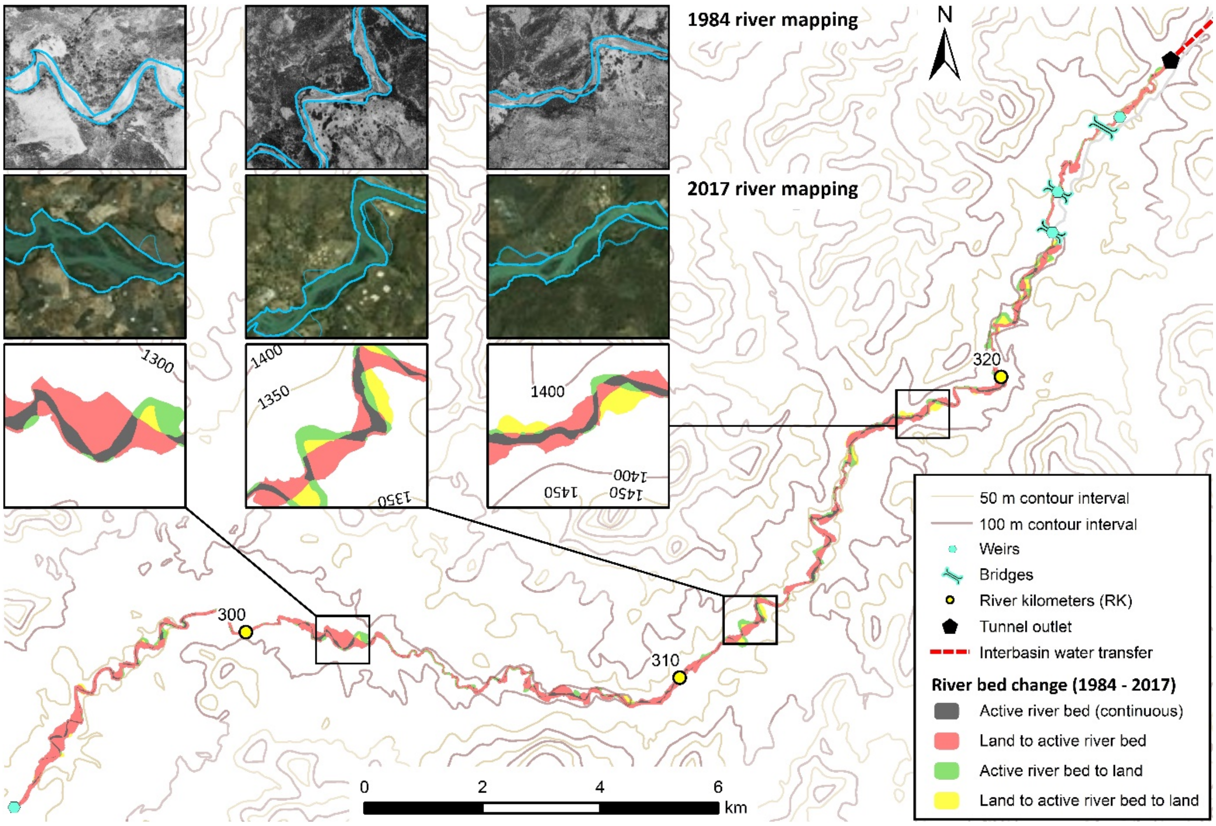

Fig. 4 Planform changes of the Beles river between 1984 and 2017: continuous river bed (grey), abandoned river bed (green) and newly established river bed (red). Transitional zones (in between the 1984 and 2017 river) and zones initially covered by the IBWT river are displayed in yellow. Contour lines highlight the locations where the valley is confined. Data sources: EMA (January 1984), DigitalGlobe (February 2017), ASTER global DEM.

Fig. 5 Planform river changes for segment RK295 to RK294 between 2005 (left), 2011 (middle) and 2017 (right): from meandering (P_T = 1.51, BI = 0) towards braiding (P_T = 1.08, BI = 7.27)

The changes in area, width and length for the 1 km-river segments (Fig. 6), show a large (spatial) variability. Width increases vary from +2 m to +161 m (av. +37 m), area increases from 0 to + 14 ha (av. +3 ha) and changes in length from -496 m to + 90 m (av. -90 m). The strongest decreases in length (e.g. between RK295 and RK294) are linked to loss of meanders and local braiding, and therefore often are accompanied by strong width increases. The lowest increases in width indicate the most confined segments along the river, without any potential for irrigation agriculture. Segments with high width increases, display more erodible, lesser confined alluvial plains.

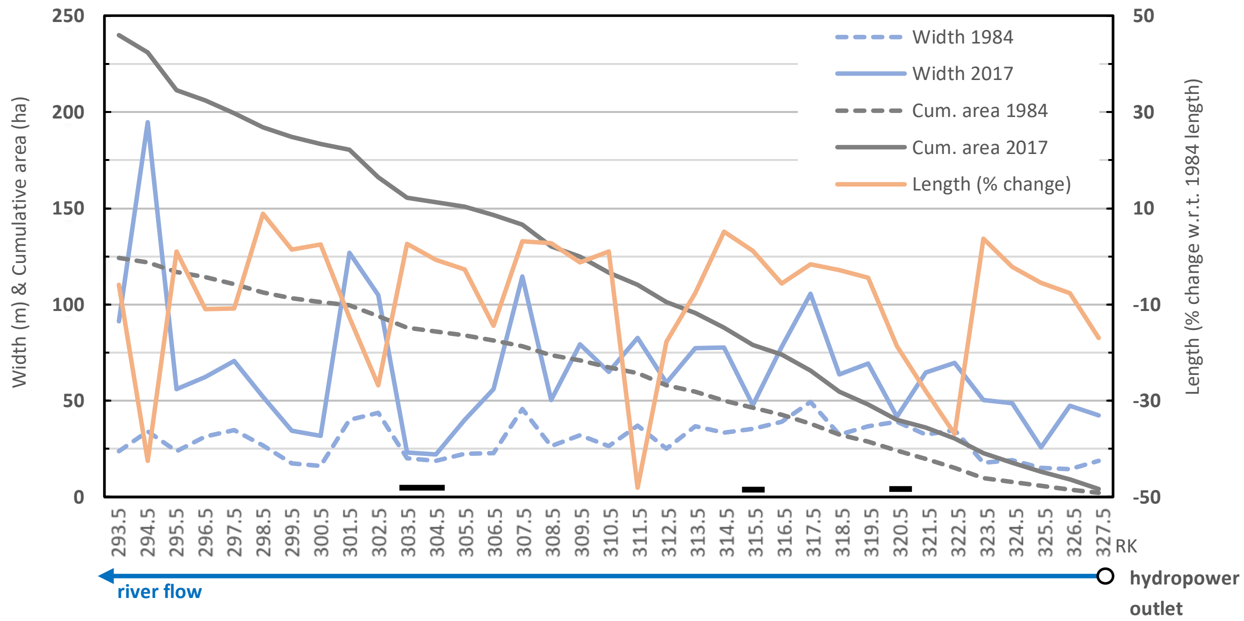

Fig. 6 Change in width (m), length (%) and area (ha) for river segments RK293 to RK328, between 1984 and 2017. As the RKs are assigned based on the 2017 situation, the length of each 2017 segment is 1000 m and therefore the relative change in length from 1984 to 2017 is given. Strongly confined segments are indicated by a black line.

4.3 Establishment of large-scale commercial farms

Due to the IBWT-induced year-round water availability, many actors started to show interest in the Beles basin, mainly for large-scale commercial farming. So far, the basin had largely remained free of large-scale developments (up to the year 2000) as it was considered (geographically) peripheral (Fantini et al., 2018; Nyssen et al., 2018). The agricultural system had persisted to consist of shifting cultivation in the lower basin and permanent (rainfed) smallholder farming in the upper basin (Nyssen et al., 2018). Since 2010, the federal government of Ethiopia and its public enterprises have actively re-shaped and re-positioned the (upper) Beles basin. First, EEPCo, supervised by MOWIE, has been responsible for the planning, implementation and operation of the Tana-Beles IBWT. EEPCo has the full monopoly on the hydropower-regulation and consequently the water-release, and thus has an important power over the downstream areas. Second, in 2011, the state-owned Ethiopian Sugar Corporation (ESC) has initiated the Beles Integrated Sugar Development project, covering 73,000 ha of land in the upper Beles and Ayma basins (north of Jawi). Nearly 21% of this area previously was under crop production, the affected communities (4310 households) are located in the districts of Jawi (74%) and Pawe (24%) in the Amhara and Benishangul-Gumuz regions respectively (ADSWE, 2012). Due to budget shortfalls and strong delays, however, the ESC reduced the command area to 50,000 ha and cancelled the construction of the third sugar factory. In December 2017, the two factories were completed for 78% and 25% (interview of ESC officer), although both were scheduled to start operating in 2014. Similar problems have been witnessed in other sugarcane projects (Kamski, 2016), indicating a structural failure. As of 2017, most of the planted 13,470 ha of sugarcane (semi-perennial crop) are 'overripe', as the sugar content drastically decreases after the age of 12 months (Hagos et al., 2014), and are no longer economically viable to be processed. Almost all canes will need to be removed and replanted in the future. Although the project is not yet operational, it has far-reaching impacts for local communities, as they were forced to resettle and restart their subsistence (mixed) farming systems. In addition to governmental interventions, a few private investors showed interest in the area as well. East of Jawi bridge, for example, an Ethiopian private investor is establishing a commercial farm of 500 up to 1000 ha for the cultivation of cotton. For this, approximately 100 households need to resettle, but no transparency is given in the project planning.

These developments force local and regional land administration offices to reinforce, actively intervene and solve many resettlement-related issues in the area. In 2005, when land certificates were officially introduced to formalize the land tenure system in Ethiopia (Crewett and Korf, 2008), most settlers in the upper Beles basin were considered illegal and did not obtain a certificate (interviews of local farmers). Many of them had informally arrived in the 1990s or early 2000s in search for land, and originate from the Amhara highlands. Some of the interviewed farmers mentioned that they were promised a land certificate, but never got one 'as there was still excess of land'. With the arrival of commercial farms, this became an important issue as people need to resettle and are not compensated with the same amount of land as they previously (informally) occupied.

4.4 Changing availability of livelihood resources

The changing context leads to changing availabilities in livelihood resources. First, water has become a permanent available and abundant resource in the area, and this has some consequences. Positive is that it leads to increased opportunities for small-scale and large-scale irrigated agriculture, permanent fresh water availability for humans and animals during the dry season. Also, fish has become much more abundant than before, as water levels used to be low in the dry season. Unfortunately, the huge increase in discharge also resulted in dangerous situations for local communities. From the hydropower outlet to Jawi bridge, over 250 people have drowned in the river, mainly in the first two years after the IBWT became operational. Most victims fell in Geneta Guhancha (103) and Belen Serkawach (71), municipalities relatively close to the outlet (Fig. 7). Initially, people were not properly informed about the IBWT (the information partly came through radio), nor were they warned about its dangers. Local people are used to frequently cross the river for various reasons (e.g. to visit family, for livestock grazing, for the market…), but they are not accustomed to the extreme high discharges and the magnitude and fast pace of changes to river stage. In the first five kilometers below the hydropower outlet, three bridges have been built, but after that, it takes 32 km and again 55 km to reach the next bridge. After facing many difficulties and dangers in the first years, people stopped crossing the river and so the Beles became a permanent physical boundary in the landscape. Consequently, people on opposite river sides stopped interacting with each other (decreasing the social capital, market opportunities and access to services) and became cut off from each other's (natural) resources (e.g. grazing land) and facilities. In addition, mainly in the first two years, a lot of livestock (> 500 cows and goats) have drowned, except near bridges and in the Jawi-Pawe area. For local farmers, livestock is crucial to their income and are an important source of animal food products.

A second important consequence is the direct loss of land and the (indirect) increasing pressure on land. In the first 35 km below the hydropower outlet, 163 ha of land have been taken by the river through bank erosion and braided river development. Most of these lands were farmlands, as they were relatively flat (average slope of 11 %), fertile (part of the alluvial plain) and consequently very attractive to farmers. More importantly, however, is the increased pressure on land. Since 2011, over 20,000 ha of land have been cleared for the development of sugarcane (Fantini et al., 2018) and 4310 households had to resettle. In Jawi district, 2930 households (average household size of 6.6 persons) have resettled in a twin-town at the eastern edge of the city of Jawi (Fig. 7 - detail). All households received compensation for houses and fruit trees, and received new land for farming. As most farmers were considered illegal land users (without land certificate), they did not receive the same amount of land as they were using before. On average, the households occupied 8.5 ha of land (this was possible due to low population densities and vastness of lands), but received 2.5 ha as compensation. Although these 2.5 ha of land will be managed more intensively, the loss of 6 ha of land is substantial and is not compensated. Due to the vicinity of the sugarcane plantation, new lands moreover are located very far from the resettlement town. Whereas the average walking distance to the land previously was 30 minutes, it now amounts 8 hours. Sometimes, the lands are already informally occupied by other farmers, which leads to conflicts that are mostly won by the present (illegal) occupiers. The distance also makes it difficult to rent out the lands. Moving permanently to the new lands is unattractive due to improved facilities and (market) accessibility in the resettlement town. Most farmers complain that the new lands are unsuitable for farming as the terrain is undulating, rocky and has shallow soils. Moreover, also grazing lands have become scarce due to the vicinity of the plantation. In Pawe district, 1276 households were resettled in the year 2013, although the plantation does not reach the territory of the district, as of October 2017. Here, the compensated lands are located closer to the two resettlement villages, and are located at on average 3.5 hours walking distance. On average, households used 3.9 ha of land before, and received 1.3 ha as compensation. The compensated lands very often were covered by bushland, so the farmers had to manually clear them. Sometimes, the farmlands also already were used by Gumuz people, leading to (ethnic) conflicts. Around the villages, grazing land is scarce, although the number of livestock is high. Farmers must walk up to three hours to reach grazing land. Frequently the livestock enter cultivated lands near the village, leading to conflicts. Both in Jawi and Pawe district, resettlement villages provide improved school and health care facilities (increasing human capital), but no electricity, asphalt roads or private water taps have been provided, although promised by the ESC.

An important consideration here is that the environmental impact assessment (EIA) of the Beles hydropower project could not be consulted for this study, as the report was unfindable at the EEP head office in Addis Ababa. Instead, the well-distributed hydrological study of the Tana-Beles sub-basins (SMEC, 2008) has been used to gather information on predicted impacts and planned mitigation measures. This study stated that bank erosion could be expected and that the high increases in discharges could lead to dangerous situations for local communities. No serious mitigation measures have been implemented and no compensation has been given to affected people.

4.5 Changing livelihood strategies and implications for livelihood outcomes

Based on the resource availability, people decide which livelihood strategy or combination of strategies they will follow to pursue the best 'livelihood outcome'. Scoones (2009) identified four strategies for rural livelihoods: agricultural intensification, agricultural extensification, diversification and migration. In this paper, we subdivide migration into migration, development induced (DI) displacement and DI resettlement, and include the option 'business as usual'. As the changing resource availability induces a strong spatial variability in livelihood strategies (Fig. 7), we discuss them accordingly.

In the upper part of the basin, the water availability relatively increased the most. Although this provides opportunities for irrigation agriculture, none of the farmers is irrigating. The reason for this is fourfold. First, the upper Beles valley is quite confined and the terrain is mostly undulating (the height above the river is indicated on Fig. 7). The slope threshold for irrigation approximately is 8%

(http://www.fao.org), and is exceeded very often nearby the river. Second, some of the most suitable lands for irrigation have been eroded by the Beles river. Third, the farmers indicate that they do not have the technical knowledge or skills to irrigate the land, although they are willing to (problem of human capital). Support from agricultural experts is lacking, although some of the farmers received a one day-training in the past. Without technical support, it is hard to make the required financial investments. Few farmers have bought an irrigation pump, but as they were not very successful in using it (low yields), they stopped and shifted back to rainfed farming. Fourth, due to the remoteness of the area, it is not convenient for the farmers to buy fuel or spare parts for the motor pumps, or to market their products. Close to the river, some farmers were able to shift from one to two harvests per year (intensification), as residual moisture is better available. Starting from just before dam implementation, an encroachment of farmlands towards the river can be observed (extensification), often at the expense of natural vegetation (environmental cost). As 163 ha of land disappeared in the upper 35 km, we estimate that approximately 450 farmers have been affected by this uncompensated loss, decreasing the food security. The affected farmers mostly rely on their social network (social security system) to cover the loss and do not change livelihood strategy. The same is true for the households that lost family members or livestock. Although the impact for many households in this upper part of the basin is far-reaching (e.g. disconnection from family members) and the general feeling about the IBWT is bad, most people opt for the 'business as usual' approach.

More downstream, the arrival of the sugarcane plantation and the related DI displacement have led to drastic (involuntary) changes in livelihood strategies. In Jawe district, the compensation farmlands are located very far from the resettlement town and consequently almost none of the farmers are using them. The few users seasonally stay overnight at their fields, making them prone to diseases such as malaria. Most farmers try to rent land close to the town, but land has become scarce and consequently also expensive for renting. Of the 45 interviewed farmers, 11 are still farming some years after resettlement, but also had to look for additional sources of income (job diversification). Job opportunities in the area are few and the demand for work highly exceeds the offer. Initially, the ESC offered jobs as daily laborer or guard in the plantation, but this number declined strongly when the planting phase was over. As the sugar factories are not yet operational, no new job opportunities are expected to come up soon. Other sources of income in the area include jobs as taxi driver, daily laborer in construction, selling wood or charcoal, selling local beer or livestock rearing. In many households, also women tried to find a full-time job after resettlement to make the ends meet. This is quite uncommon in this area, as women traditionally are already responsible for housekeeping and nursing the children, highlighting the difficult living conditions. In Pawe district, the situation is different as the plantation did not yet reach the area in 2017 and consequently also cannot provide any jobs. The shortage of land (both grazing land and farmland) and lack of job opportunities ensure that people partially have become dependent on food aid. Some farmers started to rent land from the Gumuz people in the lower part of the basin, and (seasonally) migrate. Both in Jawe and Pawe districts, the interviewed farmers stated that it has become difficult to survive after resettlement.

Clear benefits for local people only appear when we approach the town of Pawe, 100 km downstream of the hydropower outlet. Here, some well-managed irrigated lands can be found in the alluvial plains (intensification) (Fig. 7), although the total irrigated area remains small (< 50 ha). The lands are irrigated by individual farmers using pumped water from the river, and the main cultivated crops are banana, tomato, onion, cabbage and green pepper. At most plots, daily laborers are employed to cope with the increased workload. The farmers harvest twice a year - three times is not possible due to high water stands and related blight diseases - and clearly indicate to have higher revenues than non-irrigating colleagues with similar land sizes. However, storage of tomato and onion is a major problem in the area due to high temperatures, affecting market prices in peak harvest seasons (Nyssen et al., 2018). In the rainy season, the river overflows its banks and the water levels can be very high inland, leading to the dieback of perennial banana crops. This is partly caused by the raised water levels induced by the diversion dam 3.5 km downstream of Pawe bridge. Farmers indicate that the river is increasingly depositing sand in the plains, which is bad for the cultivation of some crops and already leads to lowered yields at some places. An agricultural research center with a strong focus on irrigation is located in Pawe. All smallholder irrigation farmers have received training from the center and indicate that this support has been a crucial step in shifting towards irrigation (human capital enabling financial investments). Near Pawe, the northern bank of the Beles river is part of the (future) command area of the sugarcane plantation. Local farmers are not allowed to use the lands, which limits the area suitable for irrigation. More inland, most households choose for the 'business as usual' approach, as the IBWT-induced changes in livelihood resources remain limited for them.

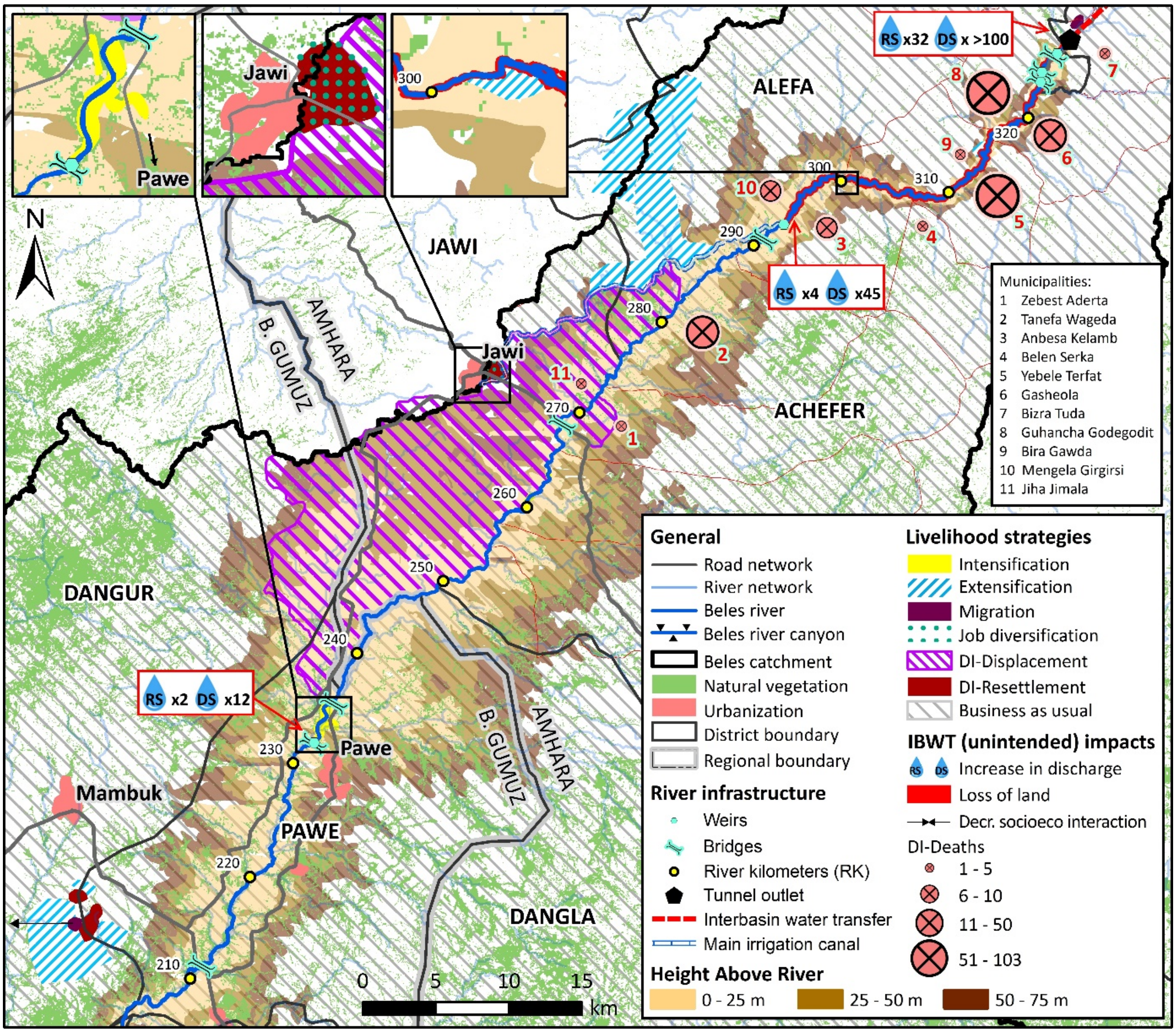

Fig. 7 Changing livelihood strategies in the upper Beles basin (RS = rainy season, DS = dry season, DI = Development Induced)

Fig. 8 Smallholder irrigation near Pawe

5. DISCUSSION

5.1 Hydrogeomorphological context: anticipation, but no mitigation or compensation

From the hydrological study of the Tana-Beles sub-basins (SMEC, 2008), it is clear that officials and the contractor Salini Impregilo were well aware of the consequences and dangers that the high diurnal variability and huge increase in average river flow could entail (Box 1). Nevertheless, local communities have not been included in the decision-making process and have not been properly informed nor warned about potential dangers, mitigation measures have proven insufficient and no compensation measures have been taken. Participatory decision-making is highly valued by the World Commission on Dams (WCD, 2000), but is considered unrealistic and constraining by the dam industry (Bosshard, 2010). All stakeholders, however, argue for a basic awareness raising and full transparency towards local people (Kibler et al., 2012). In this case, warning was done by radio only and consequently did not reach everyone (radio access in Ethiopia is among the lowest in Sub-Sahara Africa - Deininger et al., 2008). Proper awareness raising probably could have saved human lives, which is a very important lesson to be learned for the implementation of future projects, both for the Ethiopian government and for the contractor Salini Impergilo. In addition, the number of constructed bridges should have been higher to allow safe river crossing. SMEC (2008) reported the planning of five weirs and bridges, but only three of each have been constructed. The Amhara regional government and the federal government repeatedly have been informed about the situation, but did not undertake action. After the first deaths were reported, warning messages should have been distributed through different media. Due to remoteness and limited internet or phone use, the severity of the problem did not gain wider attention, partly also because the local data had never been aggregated at district or regional level. In addition to the loss of lives, officials also should have anticipated on the loss of land due to bank erosion and submersion (Box 1). Although this loss was inevitable, considering the changing hydrogeomorphological context, monetary payments or compensation farmlands should have been part of the Environmental Impact Assessment (EIA) (Bergkamp et al., 2000). This compensation cost is negligible when compared to project costs or monetary benefits derived from electricity generation. Even though EEPCo is aware about the problem, still no compensation is given. Until the river reaches a new equilibrium state, the loss of land will continue.

Box 1 – Excerpts from SMEC (2008)

[1] "*Each time that an additional turbine is brought online, this will result in a flood wave travelling downstream, which may disrupt activities along the river or may even create dangerous situations.*"

[2] "*It is also observed that the water from the power plant has a relatively low sediment load. Thus, the water may be sediment "hungry", causing significant erosion downstream […] It is not entirely clear what the physical impacts are of this dramatic increase in average river flow […] However, locally smaller strips along the river will be inundated."*

5.2 Large-scale commercial farming: a lose-lose situation

In order to meet the growing domestic demand for sugar, create employment in 'structurally weak' regions and boost foreign currency earnings, multiple large-scale sugarcane projects have been initiated in 2011 (Kamski, 2016), some before completing the feasibility study (interview of ESC officer). Most of the projects are still not operational and fail to properly compensate for the induced losses of rural livelihoods (Kamski, 2016). This leads to the question why the government focuses solely on large-scale sugar projects, if the national sugar needs also could have been addressed by small- to medium-scale projects (similar to coffee production in Ethiopia), with less drastic social impacts. In the Beles basin, the resettlement occurred in a chaotic way as no serious displacement study was carried out (interview of ESC officer). No monetary payments were provided for net losses of land and there was a general shortage of land. According to the Ethiopian law (FDRE, 2007 - Proclamation 135/2007), monetary payments should be given based on average annual yields of the expropriated lands (times ten), if no replacement lands are available, and displaced people should be assisted in livelihood restoration. The compensation scheme fails at both of these rules. It is difficult to believe that all displaced farmers were informally using the land and consequently were not entitled to compensation, especially as most people around Pawe arrived through formal resettlement in the 1980s (Wolde-Selassie, 2004). In Jawi district, highlanders spontaneously resettled, but already lived there for many years. In 2005, the authorities did not grant them land certificates, but also did not ask them to move. This shows that authorities are not able to protect public lands from illegal land users. In general, the Beles sugarcane project has been a lose-lose situation (although described as a win-win by some of the interviewees) as the objectives of the plantation are not met and the displaced people are worse off. In the future, however, the situation may improve once the factories become operational (Wilmsen, 2016) and local people may start benefiting. In the meantime, irrigation water should be supplied to counter livelihood losses and improvements to resettlement towns should be done (e.g. electricity and secure water supply, asphalt roads…).

5.3 Small-scale irrigation farming: missed opportunities

Upstream of Pawe,no shift to smallholder irrigation agriculture has been made, which is a missed opportunity for local communities. It is known that without significant technical or financial support, local people find it difficult to make the necessary investments and learn new techniques (Bazin et al., 2011). By trial and error, yields would be low in the first years and farmers may not have the motivation to continue, as was the case for some farmers in the upper part of the basin. Local authorities clearly play an important role in the support mechanism, but may also suffer shortage of human capital themselves. Providing full support could have been a way to compensate for adverse or unintended costs borne by local communities. A second irrigation canal could have been constructed at the southern river bank (see height above river at Fig. 7), to develop formal irrigation schemes for local farmers and strongly increase the area's productivity.

5.4 Project implementation: lessons to be learned

The Beles multipurpose project appears as a textbook example of (a) full top-down approaches (developer versus developee - Olivier de Sardan, 2005), (b) non-transparent project implementation, (c) non-existing benefit sharing and (d) non-existing compensation of direct and indirect costs. The EIA moreover has been considered as just a formality and a decent follow-up of the project is lacking. We strongly argue to make in-depth ex post-analyses (including field visits to rural places) mandatory for future projects, because it is extremely difficult to predict all consequences of dams or IBWTs (Bergkamp et al., 2000; Biswas, 2004; McCartney, 2007). To increase public acceptance of future projects, transparency towards local populations is a must, as is fair compensation for adverse impacts. In addition, downstream impacts should be seriously analysed, considering the interplay of biophysical and socioeconomic systems. For this, the framework of rural livelihoods (Scoones, 2009) is very suitable, because it allows to combine data from different disciplines, from a bottom-up point of view.

Although both dams and IBWTs *can be* the best solutions for water-related issues in specific contexts, their potential impacts should be thoroughly assessed and weighed against alternatives (Mehta, 2001). In this case, the Tana-Beles IBWT does not fulfill the criteria for IBWT-evaluation (Gupta & van der Zaag, 2008): there is no real surplus or deficit in either of the basins, benefits are not equitably shared, costs are not fairly compensated, there has been no participatory decision-making, risk uncertainties and knowledge gaps have not been adequately addressed. One may wonder if there were alternative ways to supply water for large-scale irrigation or electricity generation.

5.5 Additional remarks

Additional considerations are that (i) the planned irrigation developments in the Lake Tana basin (e.g. Ribb, Megech…) can harm the reliability of hydroelectricity production of the Beles station through lowered lake levels (Alemayehu et al., 2010); (ii) irrigation development in the Beles basin can delay reservoir filling of the Grand Ethiopian Renaissance Dam; and (iii) that the IBWT does not only impact the 'recipient' area, but also the area that is 'deprived' of its water resources. The natural outlet of Lake Tana is the Blue Nile river with an average annual discharge of 133 $m^3 s^{-1}$ (Dessie et al., 2015). The average discharge of the Beles hydropower outlet amounts to 92 $m^3 s^{-1}$ and thus comprises on average 69% of the natural outflow of the lake. However, in the year 2015, discharges at the Beles hydropower outlet have exceeded 133 $m^3 s^{-1}$ during 105 days of the year (also in the dry season). This is remarkable, as 2015 was one of the driest years in decades in Ethiopia. This must have impacted the lacustrine ecosystems through (temporally) lowered lake levels. In addition, also the upper Blue Nile river-dependent communities and riverine ecosystems must have been strongly impacted by the lowered water releases. So far, no studies have been published on this topic.

6. CONCLUSION

Wordlwide, the context for hydropower projects has drastically changed due to the awareness of negative and unintended impacts in the 1980s. As a result, international standards have been set. In 2000, the World Commission on Dams provided a first global review on large dams and proposed guidelines to increase their sustainability and public acceptance. Soon after, the dam industry proposed its own guidelines. Despite these well-developed standards, many hydropower projects, including the Beles multipurpose project, still fail to thoroughly assess downstream impacts and fail to account for them.

Downstream impacts of the hydropower-controlled Tana-Beles interbasin water transfer were evaluated through the framework of rural livelihoods. The changing context (including dangerously high increases in discharge, river incision, river pattern adjustments, establishment of private and governmental commercial farms and development induced displacements) was analysed and its implication for livelihood resources' availability was assessed. Livelihood strategies were identified and spatially analysed. In the upper Beles area, over 250 people drowned, people lost land (163 ha) and livestock and in general are unhappy with the IBWT. They opt for the business as usual approach, additionally to the uncompensated negative impacts. In the districts of Jawi and Pawe, the development induced resettlement has led to difficult living conditions and forced local people to diversify their economic activities, away from agriculture. The sugar factories are still not operational and in this way fail to provide job opportunities and fail to solve the national sugar shortages. Only near the town of Pawe, local communities intensified their production systems, and shifted towards the smallholder irrigation of 50 ha of land. The irrigable area is limited due to the sugarcane command area. From this analysis, it is clear that for the Tana-Beles project national development goals conflict with local development needs, and are at the expense of rural livelihoods.

Future hydropower projects are anticipated to have similar impacts although of lesser magnitude, as they regulate discharges and do not transfer water from other basins. However, important lessons should be learned: (i) local people should be properly informed and warned about the high diurnal variability and strong increase in baseflow (basic transparency); (ii) losses of land should be compensated either by accessible replacement lands or by monetary payments; (iii) developments of large-scale commercial farming should provide benefits for the displaced people or should include measures of livelihood restoration; (iv) sufficient technical support should be given to local communities in order to let them adapt to and benefit from the new context (e.g. agricultural intensification); (v) the environmental impact assessment cannot be considered just a formality. We argue for the implementation of a decent (independent) follow-up system, including field visits to areas that are difficult to access. The world still has large unexplored hydropower potentials, from which all can benefit if impacts are thoroughly assessed and externalities are internalized.

At last, we want to stress the importance of interdisciplinary evaluating hydropower projects. While hydrogeomorphological studies may disregard socioeconomic impacts, socio-political studies may not fully grasp the role of the changing hydrogeomorphological context. The framework of rural livelihoods has proven useful to bridge hydrological and socioeconomic data and allows to combine local to national level data. In addition, we argue for more attention for impacts of IBWTs on 'recipient' areas, as they clearly are not self-evidently positive.

7. ACKNOWLEDGEMENTS

This study was funded by the Flemish Research Foundation (FWO, Belgium), through project No. G022217N and a specific travel grant for a long stay abroad (No. V445417N). We acknowledge the cooperation with the Bahir Dar University VLIR-UOS IUC programme. All support given by Bahir Dar University has been greatly appreciated and many thanks go to Yonnas Shawul and Deribew Fenetie, for assisting and translating in the field. Staff of various ranks in administrative offices are thanked for their cooperation and mostly openness during interviews. Special thanks go to the local farmers and other rural dwellers, for their cooperation and contribution to this research. We thank Emanuele Fantini and an anonymous reviewer for their constructive comments.

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