

This item is the archived peer-reviewed author-version of:

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

Reference:

Anny Sofie, Adgo Enyew, Ghebreyohannes Tesfaalem, Van Passel Steven, Dessein Joost, Nyssen Jan.- Impacts of the hydropower-controlled Tana-Beles interbasin water transfer on downstream rural livelihoods (northwest Ethiopia)
Journal of hydrology - ISSN 0022-1694 - 569(2019), p. 436-448
Full text (Publisher's DOI): <https://doi.org/10.1016/J.JHYDROL.2018.12.012>
To cite this reference: <https://hdl.handle.net/10067/1569350151162165141>

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

3

4 Sofie Annys^{1,2,*}, Enyew Adgo³, Tesfaalem Ghebreyohannes⁴, Steven Van Passel^{2,5}, Joost Dessein^{6,7}, Jan Nyssen¹

5

6 ¹ Department of Geography, Ghent University, Krijgslaan 281 (S8 building), 9000 Ghent, Belgium

7 ² Department of Engineering Management, University of Antwerp, Prinsstraat 13, 2000 Antwerp, Belgium

8 ³ Department of Natural Resource Management, Bahir Dar University, P.O. Box 79, Bahir Dar, Ethiopia

9 ⁴ Department of Geography and Environmental Studies, Mekelle University, P.O. Box 231, Mekelle, Ethiopia

10 ⁵ Centre for Environmental Sciences, Hasselt University, Agoralaan (Building D), 3590 Diepenbeek, Belgium

11 ⁶ Department of Agricultural Economics, Ghent University, Coupure Links 653, 9000 Gent, Belgium

12 ⁷ Flanders Research Institute for Agriculture, Fisheries and Food, Burgemeester Van Gansberghelaan 115 bus 2,

13 9820 Merelbeke, Belgium

14 * Corresponding author: sofie.annys@ugent.be, Krijgslaan 281 (S8 building), 9000 Ghent, Belgium

15 **ABSTRACT**

16 Despite public awareness of unintended impacts (1980s) and well-developed international standards
17 (2000s), downstream impacts of large hydropower projects still very often are not properly assessed.
18 Impacts of (hydropower-regulated) interbasin water transfers (IBWTs) are considered self-evidently
19 positive, although they can have far-reaching consequences for hydrogeomorphological systems and
20 consequently river-dependent communities. In this study, the downstream direct and indirect impacts
21 of the Ethiopian hydropower-regulated Tana-Beles IBWT are evaluated in an interdisciplinary way. The
22 components of the framework of rural livelihoods are considered and changing contexts, resources'
23 availabilities and livelihood strategies are analysed. Mixed methods are applied, combining
24 hydrogeomorphological field observations, GIS analyses, scientific literature, policy documents, and
25 semi-structured interviews with local people and local to federal authorities. Results show that the
26 IBWT drastically increased the Beles river's discharge (with an average release of + 92 m³ s⁻¹ at the
27 outlet; *2 in rainy season and *12 in dry season 100 km downstream of the water release) and
28 introduced dangerous situations for local communities (over 250 people drowned in the river). River
29 bank erosion resulted in the uncompensated loss of farmland (163 ha) and the establishment of large-
30 scale commercial farms increased the pressure on land and led to the impoverishment of displaced
31 communities (4310 households). The project was implemented top-down, without any transparency,
32 benefit sharing or compensation for external costs. This stresses the importance of downstream
33 interdisciplinary impact assessments and highlights the need for decent in-depth ex post-analyses of
34 hydropower projects. Environmental impact assessments should be taken seriously and cannot be
35 considered a formality. In Ethiopia and in many developing countries, the hydropower industry is
36 booming. Although dams and IBWTs *can be* the best solution for water-related problems in specific
37 contexts, national development goals (such as the expansion of the electricity network) should not be
38 at the expense of rural livelihoods.

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

41 1. INTRODUCTION

42 Over time, more than 50,000 large dams have been constructed (Berga et al., 2006) for a variety of
43 purposes, ranging from electricity generation to flood control, water supply or irrigation development
44 (Bergkamp et al., 2000). Despite rising international tensions over water allocations (Abdelhady et al.,
45 2015) and increasing awareness of adverse and unintended impacts of hydropower projects
46 (McCartney et al., 2000; WCD, 2000), a new dam building era has arrived in the 21st century.
47 Considering the increasing demand for renewable energy and the world's unexplored hydropower
48 potential, this new wave of dam building is likely to persist (Magilligan et al., 2016), although the
49 political and institutional contexts for large-scale hydropower projects are remarkably different from
50 those of the 1980s (Bazin et al., 2011). Simultaneously with the increasing number of dams, other
51 supply-oriented hydraulic interventions, such as interbasin water transfers (IBWTs), increasingly also
52 have been implemented in the past decades. Similar to dams, IBWTs aim to fix discrepancies in water
53 resources' supply and demand and intend to induce economic development and enhance life quality
54 (Gupta and van der Zaag, 2008). IBWTs are mainly implemented in countries with unequally distributed
55 water resources (e.g. USA (Getches, 2005), China (Cai, 2008; Zhang, 2009), Brazil (de Andrade et al.,
56 2011), Lesotho and South Africa (Davies et al., 1992), Australia (Young et al., 2004)) and have far-
57 reaching impacts on the environment, altering the hydrological systems. This makes the
58 implementation of IBWTs also subject of debate (Zhang et al., 2015).

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

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

78 Up to 472 million people potentially have been affected downstream of large hydropower
79 projects (Richter et al., 2010), which is far more than the 80 million people who have been displaced
80 upstream (WCD, 2000). Despite the growing attention given to downstream impacts (e.g. Kibler et al.,
81 2012), they largely remain understudied and most large-scale projects fail to account for their effects
82 on river-dependent communities, up to hundreds of kilometres downstream of the hydropower
83 stations (Bazin et al., 2011; Richter et al., 2010). For IBWTs, most projects do not consider the
84 consequences for local communities in the 'downstream' areas, as the impacts are considered self-
85 evidently positive, except for the ecological consequences (e.g. introduction of non-native biota,
86 transmission of diseases, drastic alterations of riverine ecosystems... (Zhuang, 2016)). Most literature
87 on IBWTs focuses on impacts in the areas of origin, as these areas are deprived of water resources and
88 potentially of future developments (e.g. Bhattarai et al., 2005; Komakech et al., 2012). One of the main
89 problems is that downstream impacts are difficult to quantify in monetary terms (e.g. ecosystem
90 services), making environmental valuation necessary (Gupta and van der Zaag, 2008). Due to this
91 market failure and externalisation of costs, hydropower projects may induce welfare losses for local
92 communities (Bergkamp et al., 2000; McCartney et al., 2000). Another problem is that downstream

93 impacts - if taken into account at all - very frequently are assessed from a single discipline perspective.
94 However, in order to account as much as possible for inter-connected relationships between
95 biophysics, socioeconomics and geopolitics, interdisciplinary approaches are required (Garandean et
96 al., 2014; Kibler et al., 2012; Sneddon et al., 2002).

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

112 **2. THE BELES RIVER AND THE BELES MULTIPURPOSE PROJECT**

113 **2.1 Demand for the Tana-Beles interbasin water transfer**

114 Worldwide, most large-scale IBWTs currently occur between regions with 'water excess' and regions
115 with water shortages (i.e. 'a substantial water deficit' - Cox, 1999), to meet increasing demands for
116 urban and domestic water uses (e.g. de Andrade et al., 2011). However, this is not the case for the
117 Tana-Beles IBWT: the Beles catchment (recipient area) is considerably water-rich with an annual

118 rainfall of well over 1000 mm (NMA, 2016), has a relatively low population density and has long been
119 considered peripheral, both in terms of topography/location and (economic) development (Markakis,
120 2011). Therefore, the demand for the Tana-Beles IBWT is somehow atypical. The potential of the Beles
121 valley (large scale irrigation and hydropower development) first has been recognized in the early 20th
122 century. In the 1960s, the water transfer formally has been suggested for the first time (Arsano, 2007),
123 but it was in the 1980s that the Tana-Beles project was initiated in the context of severe droughts
124 (contractor: Salini Impregilo). For several reasons, however, the tunnel was not constructed at that
125 time (Nyssen et al., 2018; Wolde-Selassie, 2004). The 'current' Beles Multipurpose Project strongly
126 roots in the former projects, but its rationale should also be seen in the context of the government's
127 ambition to build a powerful hydropower network. With the Climate-Resilient Green Economy (CRGE)
128 strategic plan, in which the Tana-Beles area has been identified as an economic growth corridor, the
129 Ethiopian government aims to achieve a carbon-neutral middle-income status by 2025 (FDRE, 2011).
130 At the same time, it aims to reach an installed hydropower capacity of 22,000 MW by 2030 (IHA, 2017)
131 and has already invested a lot to reach this target: since 2009, the installed capacity has increased
132 sevenfold - from 580 to 4054 MW - by connecting the Tekezze (300 MW), Beles (460 MW), Gibe II
133 (420), FAN (97 MW), Gibe III (1 870 MW) and Genala Dawe (254 MW) projects to the national power
134 grid. This makes Ethiopia the number one player in Africa concerning hydropower capacity (IHA, 2017;
135 Verhoeven, 2011). However, the electric transmission lines are not yet able to transmit the total
136 amount of producible energy.

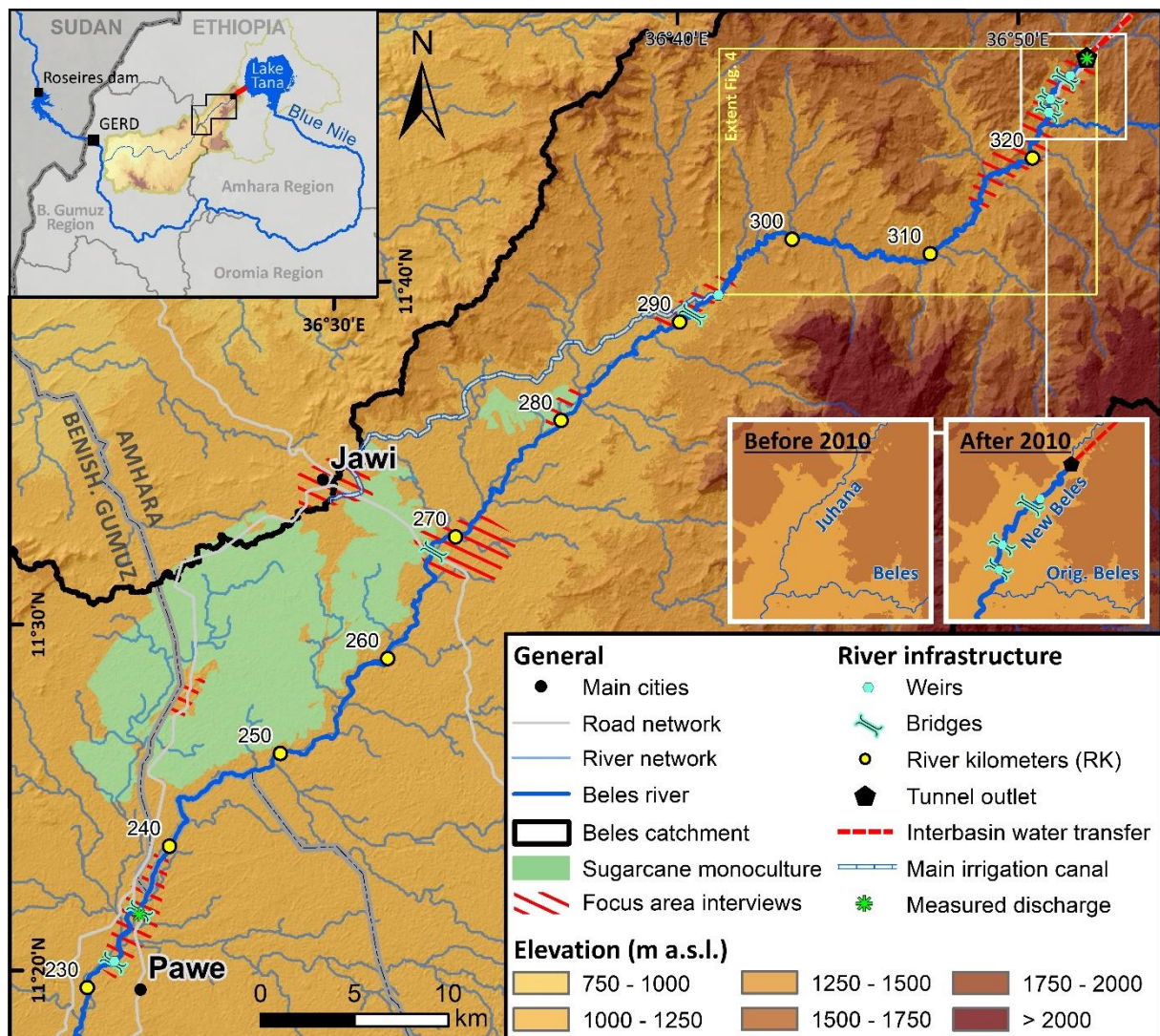
137 **2.2 Study area description and project details**

138 The Beles river is an important tributary of the Blue Nile, located in the Amhara and Benishangul-
139 Gumuz regions of northwest Ethiopia (Fig. 1). The Beles river emerges in the Tertiary trap basalts
140 southwest of Lake Tana (around 1600 m a.s.l.) and drains strongly folded and faulted Precambrian
141 rocks on its way towards the Blue Nile (Mège and Korme, 2004), which the river joins after 328 km at
142 an elevation of 540 m a.s.l. In this study, the upper 96 river kilometers (RK) of the Beles river are
143 considered (RK232 to RK328), which corresponds to a catchment area of 3050 km². Along these 96 RK,

144 the river valley is confined (upper) to semi-confined (lower), with no or small to broader alluvial plains,
145 delimiting the potentials for traditional irrigated agriculture. The area has a unimodal rainfall pattern,
146 with rain from May to October, and receives on average 1000 to 1600 mm yr⁻¹. Average minimum and
147 maximum annual temperatures are around 16°C and 33°C (NMA, 2016). Daily temperature contrasts
148 are more pronounced than seasonal contrasts, and are strongest in the dry season. Dominant land
149 cover types in this upper area are traditionally cultivated farmlands (33%), (dense) bushland (31%),
150 degraded low-vegetated land (21%), grassland (5%), sugarcane monoculture (5%) and dense forest
151 (3%) (own land cover classification, based on Sentinel-2 images, 2017). The main vegetation types are
152 ‘Combretum-Terminalia woodland and savannah’ and ‘evergreen scrub’ (Friis et al., 2010). The area
153 was initially inhabited by Gumuz people, but as a result of formal (forced) resettlement programmes
154 and spontaneous migration of Amhara, Agaw and other population groups, the Gumuz were ‘pushed’
155 towards the less accessible yet fertile lowlands (James, 1986; Wolde-Selassie, 2004).

156 Since May 2010, the Beles catchment (13,571 km²) is connected with the Tana catchment
157 (15,080 km²) by an underground IBWT from Lake Tana to the Beles valley (Fig. 1), constructed by Salini
158 Impregilo, a global player in large, complex infrastructure projects (www.salini-impregilo.com), with a
159 longstanding and controversial history of hydropower projects in Ethiopia (e.g. NCP Italy, 2017),
160 including in this study area (Fedeler, 2018; Wolde-Selassie, 2004)(Section 2.1). Starting from the tunnel
161 inlet (located at 11°53’N, 37°01’E), the lake water is transferred through a 12-km headrace tunnel
162 towards a vertical penstock, delivering water to the four hydro turbines for electricity generation (460
163 MW), using a hydraulic head of 314 m. From the powerhouse, the water is conveyed via a 7-km long
164 tailrace tunnel towards the Juhana river, an upstream tributary of the Beles river (EEPCo, 2011; SMEC,
165 2008). Five kilometers downstream of the hydropower outlet, the Juhana river joins the main Beles
166 river. The Beles river receives up to 70% of the water outflow of Lake Tana, while the remaining 30%
167 (instead of 100% before 2010) still flows towards the Blue Nile. Since 1996, the Chara-Chara weir has
168 regulated the outflow to the Blue Nile – Lake Tana is operated as a reservoir – and consequently, more
169 recently, also indirectly to the Beles river (SMEC, 2008). If lake levels are high, the Chara-Chara weir

170 spills over and releases an unregulated flow to the Blue Nile (about 110 days yr⁻¹; Interview of EEP
 171 officer). This makes the proportion of water allocated to both rivers variable trough time. A fixed
 172 release of 17 m³ s⁻¹ to the Blue Nile outlet has been proposed, with an absolute minimum of 10 m³ s⁻¹
 173 (Alemayehu et al., 2010). The Tana-Beles IBWT has a design discharge of 77 m³ s⁻¹ on average and 160
 174 m³ s⁻¹ maximum. To dissipate energy of the newly obtained high flows, three weirs have been
 175 constructed in the five kilometers downstream of the outlet (EEPCo, 2011; Fig. 1). In view of the
 176 artificial high discharges, we refer to the 'Beles river' as the lower 5 km of the Juhana river plus the
 177 'original' Beles river starting from the point of junction (Fig. 1 – inset map).



178
 179 **Fig. 1 Study area location.**

180 **3. METHODS AND MATERIALS**

181 **3.1 IBWT-induced impacts on hydrological and hydrogeomorphological context**

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

185 First, the changes to the river's discharge were studied based on the available data from the
186 Ministry of Water, Irrigation and Electricity (MoWIE) and the Ethiopian Electric Power Corporation
187 (EEPCo). Average daily discharge data for the station in Pawe (RK 232) were available from 1990 to
188 2011 (MoWIE, 1990 - 2011), and for the hydropower station (RK 328) from May 2010 up to October
189 2017 (EEPCo, 2010 - 2017). The latter consist of discharges that are estimated based on the daily energy
190 production and a project-specific conversion factor (hydrological detailed information is presented as
191 Online Supplementary Data). As no records were available for intermediate locations, for the
192 hydropower outlet before 2010 or for Pawe after 2011, the drainage area ratio method (Archfield and
193 Vogel, 2010) was applied to estimate average discharges and expand the available discharge data set.

194 Second, as no continuous records on suspended sediment load were available, we directly
195 focused on the induced second-order changes (Brandt, 2000); the cross-sectional and planform
196 changes were considered. To study the planform changes in a space-time framework, the active river
197 bed (RK328 to RK293) was mapped for the years 1984 and 2017, using aerial photographs (APs) at a
198 nominal scale of 1:50 000 (EMA, January 1984) and high-resolution satellite images (HRSIs)
199 (DigitalGlobe, February 2017). Field observations and the geo-information system 'Planet Explorer'
200 (including summer season cloud free HRSIs; www.planet.com; Taukenov et al., 2018) were additionally
201 used to map the extent of the 2017 active river bed in detail. The APs of 1984 provide the most
202 extensive cover of the 'pre-IBWT river' and it was assumed that the Beles river had reached an
203 equilibrium state before 1984 (sensu Brandt, 2000) and consequently (almost) did not change up to
204 2010. This assumption was verified for segments RK312 to RK303 in 2002 and RK297 to RK293 in 2005,
205 using available 'historical' HRSIs in Google Earth (DigitalGlobe). Pre-processing of the set of seven 1984
206 APs consisted of (i) optimizing the image contrast and brightness in Adobe Photoshop, (ii) ortho-

207 mosaicking the photographs in Agisoft PhotoScan Pro using the integrated semi-automatic SfM-MVS
208 algorithm (Verhoeven et al., 2013) and (iii) georeferencing the clipped ortho-mosaic (1.5 km-buffer
209 along river) in WGS84 in ArcMap 10.4 using 40 ground control points (0.48 points per km², RMSE of
210 4.49 m). DigitalGlobe HRSIs of the years 2011 (RK328 to RK321, RK300 to RK293) and 2013 (RK328 to
211 RK313) allowed to locally map intermediate changes after the IBWT became operational. For each river
212 segment (delineated by the RKs), the following measures were calculated and compared over time:
213 average width (m), length of centerline (m) and area (ha) (Michalkova et al., 2011). The sinuosity (P_T)
214 and braiding index (BI) of the considered river stretch were calculated as follows:

215
$$P_T = \frac{L_{CMAX}}{L_R}; L_{CMAX} = \text{length of channel centerline, } L_R = \text{reach length (thalweg) (Friend and Sinha, 1993)}$$

216
$$BI = 2 \sum \frac{L_B}{L_R} + \sum \frac{N_B}{L_R}; L_B = \text{bar length, } L_R = \text{reach length (thalweg), } N_B = \text{number of bars (Germanoski and}$$

217 Schumm, 1993)

218 In January and October 2017, extensive field visits were done in the study area and
219 observations of channel incision were made based on the presence of undermined bridges (Kondolf,
220 1997) and ancient river courses well above the current course of the Beles river. The latter were
221 identified in the field by the presence of rounded pebbles and sprouting/young vegetation, and were
222 dated by interviews and DigitalGlobe HRSIs (Google Earth).

223 **3.2 IBWT-induced impacts on socioeconomic and institutional context**

224 Local socioeconomic and institutional contexts are expected to change drastically due to the
225 hydrological changes induced by the IBWT. It is expected that many new players will enter the
226 development arena (Olivier de Sardan, 2005) (e.g. private investors, governmental and non-
227 governmental organizations...) as the permanent water availability makes the area suitable for (large-
228 scale commercial) irrigated agriculture. To study how the socioeconomic and institutional contexts
229 have changed exactly after the implementation of the IBWT, existing scientific literature and policy
230 reports regarding developments in the upper Beles basin were consulted. During the field visits in
231 2017, municipal and district chairmen were interviewed to obtain additional information on ongoing

232 and planned large-scale interventions. The Beles integrated sugarcane development project office, the
 233 EEP head office, ESC head office and MoWIE - EIA & Social Development Office in Addis Ababa were
 234 visited to interview civil servants on the implementation of the Beles multipurpose project and related
 235 institutional changes (Table 1). Summaries of the interviews were transcribed and were encoded using
 236 NVivo 11 software for processing.

237 **Table 1 Location, category and number of semi-structured interviews used to study IBWT-induced**
 238 **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

239 **3.3 IBWT-induced impacts on livelihood strategies**

240 To study how local communities have responded to IBWT-induced contextual changes, we investigated
 241 how the (livelihood) resource availability has changed over time and how this changing availability has
 242 impacted livelihood strategies. Based on Scoones' (2009) framework of rural livelihoods, the impacts
 243 on natural, human, social, economic and physical capital were examined (with a main focus on natural
 244 capital) and their implications for the different livelihood strategies (i.e. intensification, extensification,
 245 diversification and migration) were assessed. For this, semi-structured interviews with local people
 246 and local authorities were conducted (Table 1). Respondents spatially distributed along the Beles river
 247 were consulted (Fig. 1), until the point of data saturation was reached for a certain sub-area. However,
 248 some parts of the study area were inaccessible due to the mountainous character of the terrain, the
 249 high vegetation density and the lack of access roads. The focus during the interviews was on how local
 250 communities have experienced the implementation of the IBWT, how the IBWT has changed daily life

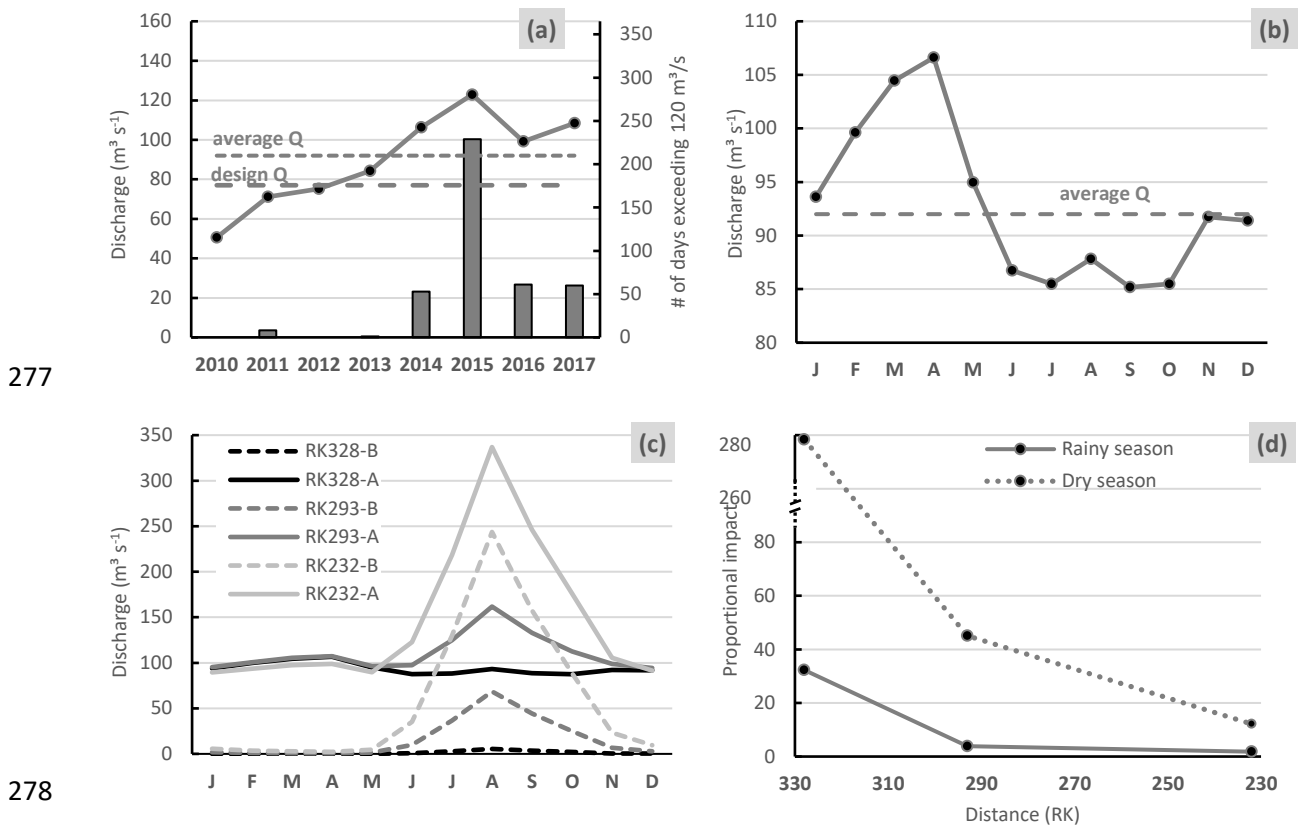
251 practices and whether it has been a positive evolution for the area. Another focus was on why some
252 people make a shift towards another livelihood strategy and others do not. The resources required to
253 make a particular shift were identified.

254 **4. RESULTS**

255 **4.1 First-order changes of the fluvial system: water and sediment flow**

256 The discharge of the Beles river has tremendously increased due to the IBWT (Fig. 2). Since 2010, an
257 average of $2.81 \cdot 10^9$ m³ water has yearly entered the Beles basin. This corresponds to an additional
258 average discharge of 92 m³ s⁻¹ at the hydropower outlet, which is well above the planned design
259 discharge of 77 m³ s⁻¹ (SMEC, 2008). Through time, the average water transfer has increased steadily,
260 with a peak in 2015, when the average daily discharge exceeded 120 m³ s⁻¹ almost 230 days (Fig. 2a).
261 Although it was anticipated that the peak discharges of the hydropower outlet would coincide with
262 natural peak discharges (SMEC, 2008), this is not the case. Over time, the average monthly discharges
263 at the hydropower outlet have been the highest during the dry season, in the months of February to
264 April (Fig. 2b). While the average discharges for the rainy season months (May to October) increased
265 with factor 32 at the hydropower outlet, the average discharges for the dry season months (November
266 to April) increased well over a hundredfold. Downstream, the proportional impact decreases strongly
267 with distance, but remains considerably high for the first 100 km. At RK293 (upstream of the main
268 irrigation canal intake), discharges in the rainy season increased fourfold and increased with factor 45
269 for the dry season months. At RK293, about 10 m³ s⁻¹ water is diverted from the river to irrigate the
270 sugarcane plantation in the dry season (interview of ESC officer). Due to clogging of the main canal,
271 however, irrigation water has not been permanently used over time. In Pawe (RK232), the discharges
272 almost doubled for the rainy season and increased with factor 12 for the dry season (Fig. 2c-d). In
273 addition to strong increases in average daily to seasonal discharges, the diurnal pattern of the river
274 flow has changed as well (Fig. 3). In correspondence with the electricity demand, discharges vary

275 strongly throughout the day, with peaks in the morning and evening near the hydropower outlet. Every
 276 time an additional turbine is brought online, a flood wave travels down the river.



279 **Fig. 2 Discharge characteristics of the Beles river after IBWT: (a) Average yearly discharge at RK328**
 280 **(hydropower outlet) (solid line) and number of days exceeding $120 \text{ m}^3 \text{ s}^{-1}$ (stack bars); (b) Average**
 281 **monthly discharge at RK328; (c) Average monthly discharge before (-B) and after (-A) IBWT**
 282 **implementation at RK328, RK293 (upstream of main irrigation canal intake) and RK232 (Pawe); (d)**
 283 **Proportional increase in seasonal average discharges at RK328, RK293 and RK232. Data sources:**
 284 **MoWIE (1990 - 2011), EEPCo (2010 - 2017), drainage area ratio method (Archfield and Vogel, 2010).**



285

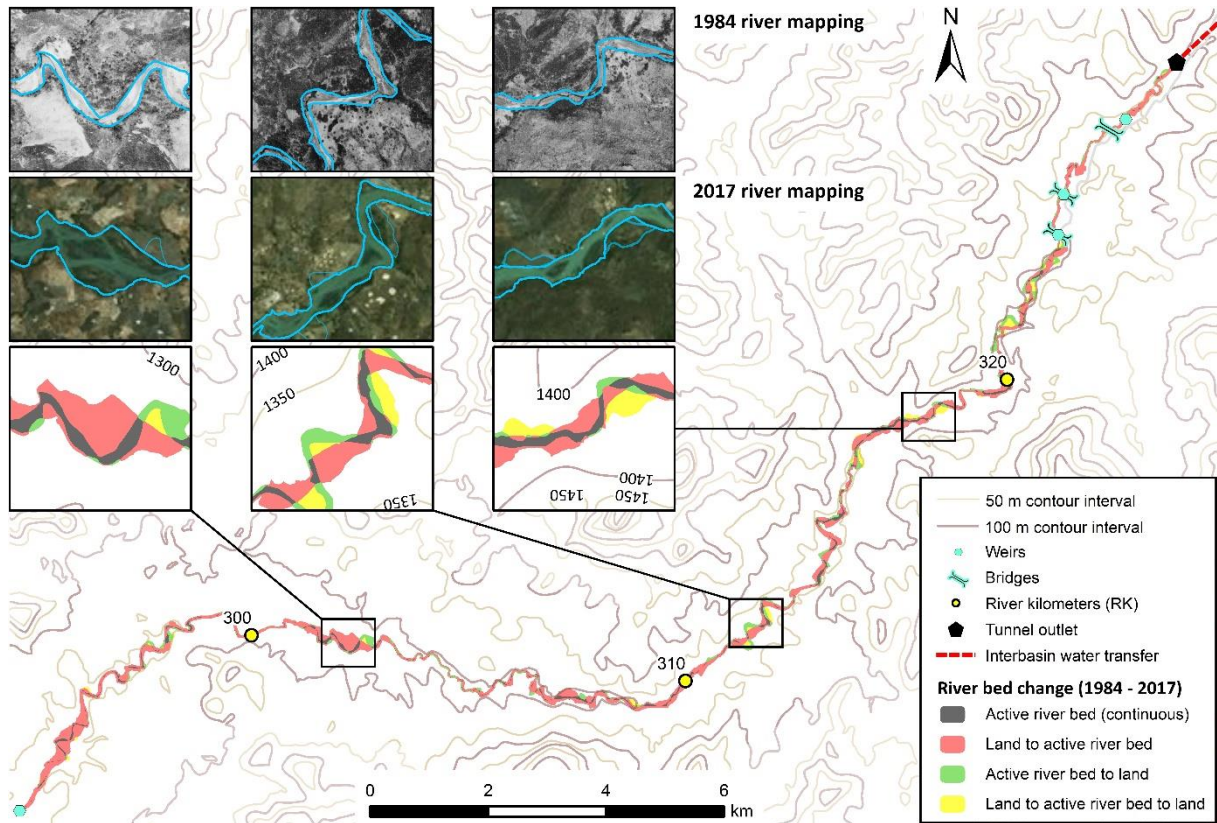
286 **Fig. 3 High diurnal variability in river discharge at RK268 (Jawi bridge): photos taken at 1 PM (left)**
287 **and 3 PM (right), on 23 January 2017 (Details in supplementary data Fig. F).**

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

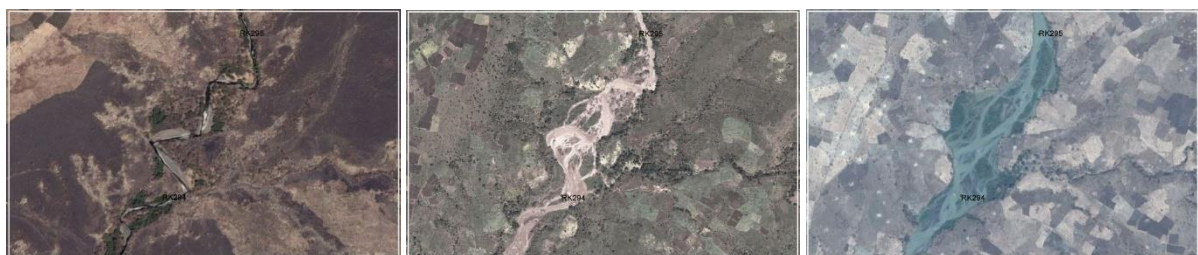
295 **4.2 Second-order changes of the fluvial system: planform configuration**

296 In addition to observations of river incision, many observations of lateral erosion were made, which
297 can be attributed to the clear water effect and increase in discharge (Brandt, 2000). As it has important
298 impacts for local farmers, the extent of the lateral erosion was quantified by mapping the planform
299 changes for segments RK328 to RK293. The active river bed was mapped for the years 1984 and 2017.
300 Based on the overlay of both maps, planform changes were visualized (Fig. 4) and quantified. Between
301 1984 and 2017, 90.6 ha continuously was active river bed (grey), 25.6 ha was abandoned by the river
302 (green) and 141.2 (red) ha of land was taken by the river (162.7 ha if we include intermediate changes,
303 red + yellow). The total area of active river bed almost doubled, from 124 ha to 240 ha (+94%), and the
304 average width of the river increased from 29.3 m to 66.5 m (+127%). The length of the centerline of

305 the river declined from 38.8 km in 1984 to 35.5 km in 2017 (-8.5%). Accordingly, the sinuosity of the
 306 river decreased from 1.34 to 1.23 (river straightening). The strong confinement constrains the river to
 307 become completely straight (sinuosity < 1.1). Locally, the river adopted a braided river pattern (Fig. 5).

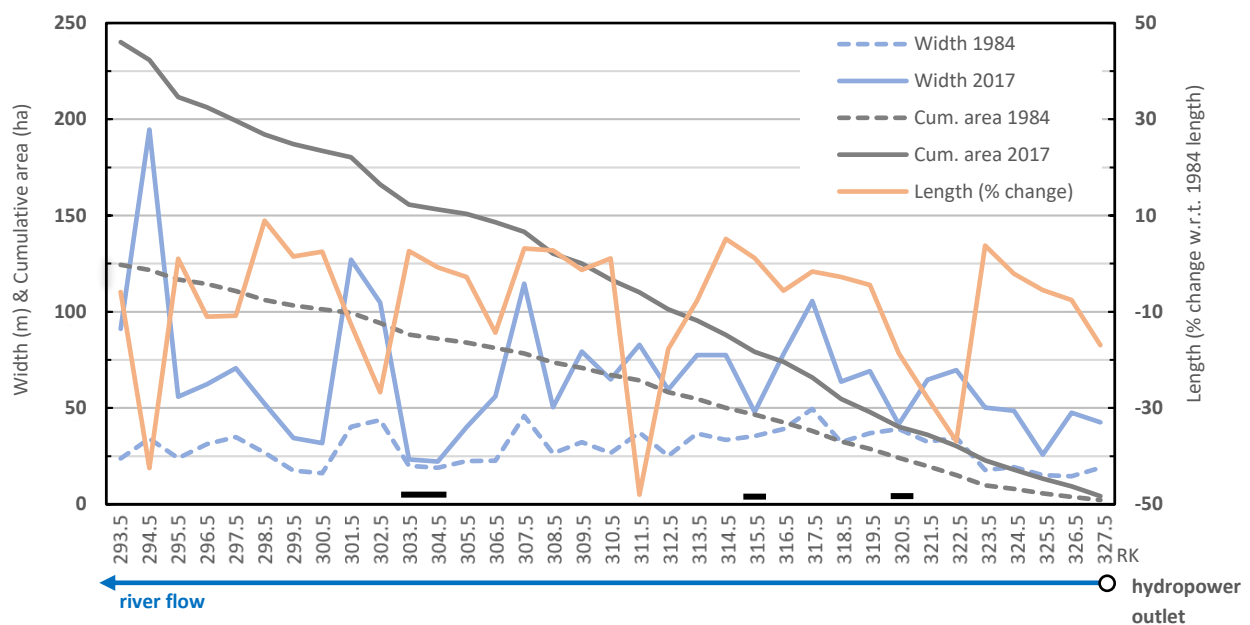


308
 309 **Fig. 4 Planform changes of the Beles river between 1984 and 2017: continuous river bed (grey),**
 310 **abandoned river bed (green) and newly established river bed (red). Transitional zones (in between**
 311 **the 1984 and 2017 river) and zones initially covered by the IBWT river are displayed in yellow.**
 312 **Contour lines highlight the locations where the valley is confined. Data sources: EMA (January 1984),**
 313 **DigitalGlobe (February 2017), ASTER global DEM.**



314
 315 **Fig. 5 Planform river changes for segment RK295 to RK294 between 2005 (left), 2011 (middle) and**
 316 **2017 (right): from meandering ($P_T = 1.51$, $BI = 0$) towards braiding ($P_T = 1.08$, $BI = 7.27$)**

317 The changes in area, width and length for the 1 km-river segments (Fig. 6), show a large
 318 (spatial) variability. Width increases vary from +2 m to +161 m (av. +37 m), area increases from 0 to +
 319 14 ha (av. +3 ha) and changes in length from -496 m to + 90 m (av. -90 m). The strongest decreases in
 320 length (e.g. between RK295 and RK294) are linked to loss of meanders and local braiding, and therefore
 321 often are accompanied by strong width increases. The lowest increases in width indicate the most
 322 confined segments along the river, without any potential for irrigation agriculture. Segments with high
 323 width increases, display more erodible, lesser confined alluvial plains.



324
 325 **Fig. 6 Change in width (m), length (%) and area (ha) for river segments RK293 to RK328, between**
 326 **1984 and 2017. As the RKs are assigned based on the 2017 situation, the length of each 2017 segment**
 327 **is 1000 m and therefore the relative change in length from 1984 to 2017 is given. Strongly confined**
 328 **segments are indicated by a black line.**

329 4.3 Establishment of large-scale commercial farms

330 Due to the IBWT-induced year-round water availability, many actors started to show interest in the
 331 Beles basin, mainly for large-scale commercial farming. So far, the basin had largely remained free of
 332 large-scale developments (up to the year 2000) as it was considered (geographically) peripheral
 333 (Fantini et al., 2018; Nyssen et al., 2018). The agricultural system had persisted to consist of shifting

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

357 These developments force local and regional land administration offices to reinforce, actively
358 intervene and solve many resettlement-related issues in the area. In 2005, when land certificates were
359 officially introduced to formalize the land tenure system in Ethiopia (Crewett and Korf, 2008), most

360 settlers in the upper Beles basin were considered illegal and did not obtain a certificate (interviews of
361 local farmers). Many of them had informally arrived in the 1990s or early 2000s in search for land, and
362 originate from the Amhara highlands. Some of the interviewed farmers mentioned that they were
363 promised a land certificate, but never got one 'as there was still excess of land'. With the arrival of
364 commercial farms, this became an important issue as people need to resettle and are not compensated
365 with the same amount of land as they previously (informally) occupied.

366 **4.4 Changing availability of livelihood resources**

367 The changing context leads to changing availabilities in livelihood resources. First, water has become
368 a permanent available and abundant resource in the area, and this has some consequences. Positive
369 is that it leads to increased opportunities for small-scale and large-scale irrigated agriculture,
370 permanent fresh water availability for humans and animals during the dry season. Also, fish has
371 become much more abundant than before, as water levels used to be low in the dry season.
372 Unfortunately, the huge increase in discharge also resulted in dangerous situations for local
373 communities. From the hydropower outlet to Jawi bridge, over 250 people have drowned in the river,
374 mainly in the first two years after the IBWT became operational. Most victims fell in Geneta Guhancha
375 (103) and Belen Serkawach (71), municipalities relatively close to the outlet (Fig. 7). Initially, people
376 were not properly informed about the IBWT (the information partly came through radio), nor were
377 they warned about its dangers. Local people are used to frequently cross the river for various reasons
378 (e.g. to visit family, for livestock grazing, for the market...), but they are not accustomed to the extreme
379 high discharges and the magnitude and fast pace of changes to river stage. In the first five kilometers
380 below the hydropower outlet, three bridges have been built, but after that, it takes 32 km and again
381 55 km to reach the next bridge. After facing many difficulties and dangers in the first years, people
382 stopped crossing the river and so the Beles became a permanent physical boundary in the landscape.
383 Consequently, people on opposite river sides stopped interacting with each other (decreasing the
384 social capital, market opportunities and access to services) and became cut off from each other's
385 (natural) resources (e.g. grazing land) and facilities. In addition, mainly in the first two years, a lot of

386 livestock (> 500 cows and goats) have drowned, except near bridges and in the Jawi-Pawe area. For
387 local farmers, livestock is crucial to their income and are an important source of animal food products.

388 A second important consequence is the direct loss of land and the (indirect) increasing
389 pressure on land. In the first 35 km below the hydropower outlet, 163 ha of land have been taken by
390 the river through bank erosion and braided river development. Most of these lands were farmlands,
391 as they were relatively flat (average slope of 11 %), fertile (part of the alluvial plain) and consequently
392 very attractive to farmers. More importantly, however, is the increased pressure on land. Since 2011,
393 over 20,000 ha of land have been cleared for the development of sugarcane (Fantini et al., 2018) and
394 4310 households had to resettle. In Jawi district, 2930 households (average household size of 6.6
395 persons) have resettled in a twin-town at the eastern edge of the city of Jawi (Fig. 7 - detail). All
396 households received compensation for houses and fruit trees, and received new land for farming. As
397 most farmers were considered illegal land users (without land certificate), they did not receive the
398 same amount of land as they were using before. On average, the households occupied 8.5 ha of land
399 (this was possible due to low population densities and vastness of lands), but received 2.5 ha as
400 compensation. Although these 2.5 ha of land will be managed more intensively, the loss of 6 ha of land
401 is substantial and is not compensated. Due to the vicinity of the sugarcane plantation, new lands
402 moreover are located very far from the resettlement town. Whereas the average walking distance to
403 the land previously was 30 minutes, it now amounts 8 hours. Sometimes, the lands are already
404 informally occupied by other farmers, which leads to conflicts that are mostly won by the present
405 (illegal) occupiers. The distance also makes it difficult to rent out the lands. Moving permanently to the
406 new lands is unattractive due to improved facilities and (market) accessibility in the resettlement town.
407 Most farmers complain that the new lands are unsuitable for farming as the terrain is undulating, rocky
408 and has shallow soils. Moreover, also grazing lands have become scarce due to the vicinity of the
409 plantation. In Pawe district, 1276 households were resettled in the year 2013, although the plantation
410 does not reach the territory of the district, as of October 2017. Here, the compensated lands are
411 located closer to the two resettlement villages, and are located at on average 3.5 hours walking

412 distance. On average, households used 3.9 ha of land before, and received 1.3 ha as compensation.
413 The compensated lands very often were covered by bushland, so the farmers had to manually clear
414 them. Sometimes, the farmlands also already were used by Gumuz people, leading to (ethnic) conflicts.
415 Around the villages, grazing land is scarce, although the number of livestock is high. Farmers must walk
416 up to three hours to reach grazing land. Frequently the livestock enter cultivated lands near the village,
417 leading to conflicts. Both in Jawi and Pawe district, resettlement villages provide improved school and
418 health care facilities (increasing human capital), but no electricity, asphalt roads or private water taps
419 have been provided, although promised by the ESC.

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

427 **4.5 Changing livelihood strategies and implications for livelihood outcomes**

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

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

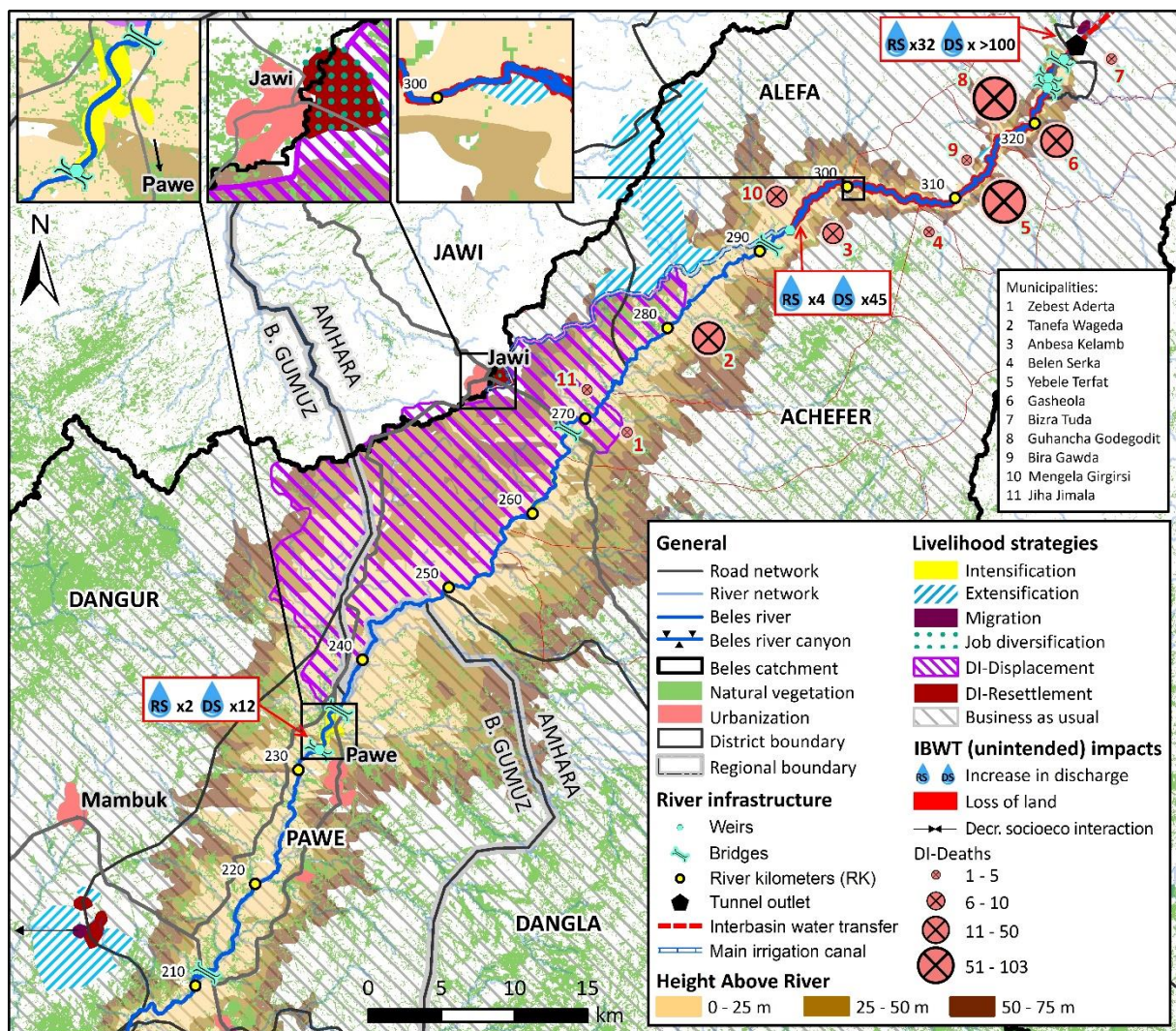
438 (<http://www.fao.org>), and is exceeded very often nearby the river. Second, some of the most suitable
439 lands for irrigation have been eroded by the Beles river. Third, the farmers indicate that they do not
440 have the technical knowledge or skills to irrigate the land, although they are willing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

456 More downstream, the arrival of the sugarcane plantation and the related DI displacement
457 have led to drastic (involuntary) changes in livelihood strategies. In Jawe district, the compensation
458 farmlands are located very far from the resettlement town and consequently almost none of the
459 farmers are using them. The few users seasonally stay overnight at their fields, making them prone to
460 diseases such as malaria. Most farmers try to rent land close to the town, but land has become scarce
461 and consequently also expensive for renting. Of the 45 interviewed farmers, 11 are still farming some
462 years after resettlement, but also had to look for additional sources of income (job diversification). Job
463 opportunities in the area are few and the demand for work highly exceeds the offer. Initially, the ESC

464 offered jobs as daily laborer or guard in the plantation, but this number declined strongly when the
465 planting phase was over. As the sugar factories are not yet operational, no new job opportunities are
466 expected to come up soon. Other sources of income in the area include jobs as taxi driver, daily laborer
467 in construction, selling wood or charcoal, selling local beer or livestock rearing. In many households,
468 also women tried to find a full-time job after resettlement to make the ends meet. This is quite
469 uncommon in this area, as women traditionally are already responsible for housekeeping and nursing
470 the children, highlighting the difficult living conditions. In Pawe district, the situation is different as the
471 plantation did not yet reach the area in 2017 and consequently also cannot provide any jobs. The
472 shortage of land (both grazing land and farmland) and lack of job opportunities ensure that people
473 partially have become dependent on food aid. Some farmers started to rent land from the Gumuz
474 people in the lower part of the basin, and (seasonally) migrate. Both in Jawe and Pawe districts, the
475 interviewed farmers stated that it has become difficult to survive after resettlement.

476 Clear benefits for local people only appear when we approach the town of Pawe, 100 km
477 downstream of the hydropower outlet. Here, some well-managed irrigated lands can be found in the
478 alluvial plains (intensification) (Fig. 7), although the total irrigated area remains small (< 50 ha). The
479 lands are irrigated by individual farmers using pumped water from the river, and the main cultivated
480 crops are banana, tomato, onion, cabbage and green pepper. At most plots, daily laborers are
481 employed to cope with the increased workload. The farmers harvest twice a year - three times is not
482 possible due to high water stands and related blight diseases - and clearly indicate to have higher
483 revenues than non-irrigating colleagues with similar land sizes. However, storage of tomato and onion
484 is a major problem in the area due to high temperatures, affecting market prices in peak harvest
485 seasons (Nyssen et al., 2018). In the rainy season, the river overflows its banks and the water levels
486 can be very high inland, leading to the dieback of perennial banana crops. This is partly caused by the
487 raised water levels induced by the diversion dam 3.5 km downstream of Pawe bridge. Farmers indicate
488 that the river is increasingly depositing sand in the plains, which is bad for the cultivation of some crops
489 and already leads to lowered yields at some places. An agricultural research center with a strong focus

490 on irrigation is located in Pawe. All smallholder irrigation farmers have received training from the
 491 center and indicate that this support has been a crucial step in shifting towards irrigation (human
 492 capital enabling financial investments). Near Pawe, the northern bank of the Beles river is part of the
 493 (future) command area of the sugarcane plantation. Local farmers are not allowed to use the lands,
 494 which limits the area suitable for irrigation. More inland, most households choose for the 'business as
 495 usual' approach, as the IBWT-induced changes in livelihood resources remain limited for them.



496
 497 **Fig. 7 Changing livelihood strategies in the upper Beles basin (RS = rainy season, DS = dry season, DI**
 498 **= Development Induced)**



499

500 **Fig. 8 Smallholder irrigation near Pawe**

501 **5. DISCUSSION**

502 **5.1 Hydrogeomorphological context: anticipation, but no mitigation or compensation**

503 From the hydrological study of the Tana-Beles sub-basins (SMEC, 2008), it is clear that officials and the
504 contractor Salini Impregilo were well aware of the consequences and dangers that the high diurnal
505 variability and huge increase in average river flow could entail (Box 1). Nevertheless, local communities
506 have not been included in the decision-making process and have not been properly informed nor
507 warned about potential dangers, mitigation measures have proven insufficient and no compensation
508 measures have been taken. Participatory decision-making is highly valued by the World Commission
509 on Dams (WCD, 2000), but is considered unrealistic and constraining by the dam industry (Bosshard,
510 2010). All stakeholders, however, argue for a basic awareness raising and full transparency towards
511 local people (Kibler et al., 2012). In this case, warning was done by radio only and consequently did not
512 reach everyone (radio access in Ethiopia is among the lowest in Sub-Sahara Africa - Deininger et al.,
513 2008). Proper awareness raising probably could have saved human lives, which is a very important
514 lesson to be learned for the implementation of future projects, both for the Ethiopian government and
515 for the contractor Salini Impregilo. In addition, the number of constructed bridges should have been

516 higher to allow safe river crossing. SMEC (2008) reported the planning of five weirs and bridges, but
517 only three of each have been constructed. The Amhara regional government and the federal
518 government repeatedly have been informed about the situation, but did not undertake action. After
519 the first deaths were reported, warning messages should have been distributed through different
520 media. Due to remoteness and limited internet or phone use, the severity of the problem did not gain
521 wider attention, partly also because the local data had never been aggregated at district or regional
522 level. In addition to the loss of lives, officials also should have anticipated on the loss of land due to
523 bank erosion and submersion (Box 1). Although this loss was inevitable, considering the changing
524 hydrogeomorphological context, monetary payments or compensation farmlands should have been
525 part of the Environmental Impact Assessment (EIA) (Bergkamp et al., 2000). This compensation cost is
526 negligible when compared to project costs or monetary benefits derived from electricity generation.
527 Even though EEPCo is aware about the problem, still no compensation is given. Until the river reaches
528 a new equilibrium state, the loss of land will continue.

529 **Box 1 – Excerpts from SMEC (2008)**

530 [1] *“Each time that an additional turbine is brought online, this will result in a flood wave travelling downstream, which may*
531 *disrupt activities along the river or may even create dangerous situations.”*

532 [2] *“It is also observed that the water from the power plant has a relatively low sediment load. Thus, the water may be*
533 *sediment “hungry”, causing significant erosion downstream [...] It is not entirely clear what the physical impacts are of this*
534 *dramatic increase in average river flow [...] However, locally smaller strips along the river will be inundated.”*

535 **5.2 Large-scale commercial farming: a lose-lose situation**

536 In order to meet the growing domestic demand for sugar, create employment in ‘structurally weak’
537 regions and boost foreign currency earnings, multiple large-scale sugarcane projects have been
538 initiated in 2011 (Kamski, 2016), some before completing the feasibility study (interview of ESC officer).
539 Most of the projects are still not operational and fail to properly compensate for the induced losses of
540 rural livelihoods (Kamski, 2016). This leads to the question why the government focuses solely on large-
541 scale sugar projects, if the national sugar needs also could have been addressed by small- to medium-
542 scale projects (similar to coffee production in Ethiopia), with less drastic social impacts. In the Beles

543 basin, the resettlement occurred in a chaotic way as no serious displacement study was carried out
544 (interview of ESC officer). No monetary payments were provided for net losses of land and there was
545 a general shortage of land. According to the Ethiopian law (FDRE, 2007 - Proclamation 135/2007),
546 monetary payments should be given based on average annual yields of the expropriated lands (times
547 ten), if no replacement lands are available, and displaced people should be assisted in livelihood
548 restoration. The compensation scheme fails at both of these rules. It is difficult to believe that all
549 displaced farmers were informally using the land and consequently were not entitled to compensation,
550 especially as most people around Pawe arrived through formal resettlement in the 1980s (Wolde-
551 Selassie, 2004). In Jawi district, highlanders spontaneously resettled, but already lived there for many
552 years. In 2005, the authorities did not grant them land certificates, but also did not ask them to move.
553 This shows that authorities are not able to protect public lands from illegal land users. In general, the
554 Beles sugarcane project has been a lose-lose situation (although described as a win-win by some of the
555 interviewees) as the objectives of the plantation are not met and the displaced people are worse off.
556 In the future, however, the situation may improve once the factories become operational (Wilmsen,
557 2016) and local people may start benefiting. In the meantime, irrigation water should be supplied to
558 counter livelihood losses and improvements to resettlement towns should be done (e.g. electricity and
559 secure water supply, asphalt roads...).

560 **5.3 Small-scale irrigation farming: missed opportunities**

561 Upstream of Pawe, no shift to smallholder irrigation agriculture has been made, which is a missed
562 opportunity for local communities. It is known that without significant technical or financial support,
563 local people find it difficult to make the necessary investments and learn new techniques (Bazin et al.,
564 2011). By trial and error, yields would be low in the first years and farmers may not have the motivation
565 to continue, as was the case for some farmers in the upper part of the basin. Local authorities clearly
566 play an important role in the support mechanism, but may also suffer shortage of human capital
567 themselves. Providing full support could have been a way to compensate for adverse or unintended

568 costs borne by local communities. A second irrigation canal could have been constructed at the
569 southern river bank (see height above river at Fig. 7), to develop formal irrigation schemes for local
570 farmers and strongly increase the area's productivity.

571 **5.4 Project implementation: lessons to be learned**

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

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

590 **5.5 Additional remarks**

591 Additional considerations are that (i) the planned irrigation developments in the Lake Tana basin (e.g.
592 Ribb, Megech...) can harm the reliability of hydroelectricity production of the Beles station through

593 lowered lake levels (Alemayehu et al., 2010); (ii) irrigation development in the Beles basin can delay
594 reservoir filling of the Grand Ethiopian Renaissance Dam; and (iii) that the IBWT does not only impact
595 the 'recipient' area, but also the area that is 'deprived' of its water resources. The natural outlet of
596 Lake Tana is the Blue Nile river with an average annual discharge of $133 \text{ m}^3 \text{ s}^{-1}$ (Dessie et al., 2015). The
597 average discharge of the Beles hydropower outlet amounts to $92 \text{ m}^3 \text{ s}^{-1}$ and thus comprises on average
598 69% of the natural outflow of the lake. However, in the year 2015, discharges at the Beles hydropower
599 outlet have exceeded $133 \text{ m}^3 \text{ s}^{-1}$ during 105 days of the year (also in the dry season). This is remarkable,
600 as 2015 was one of the driest years in decades in Ethiopia. This must have impacted the lacustrine
601 ecosystems through (temporally) lowered lake levels. In addition, also the upper Blue Nile river-
602 dependent communities and riverine ecosystems must have been strongly impacted by the lowered
603 water releases. So far, no studies have been published on this topic.

604 **6. CONCLUSION**

605 Worldwide, the context for hydropower projects has drastically changed due to the awareness of
606 negative and unintended impacts in the 1980s. As a result, international standards have been set. In
607 2000, the World Commission on Dams provided a first global review on large dams and proposed
608 guidelines to increase their sustainability and public acceptance. Soon after, the dam industry
609 proposed its own guidelines. Despite these well-developed standards, many hydropower projects,
610 including the Beles multipurpose project, still fail to thoroughly assess downstream impacts and fail to
611 account for them.

612 Downstream impacts of the hydropower-controlled Tana-Beles interbasin water transfer were
613 evaluated through the framework of rural livelihoods. The changing context (including dangerously
614 high increases in discharge, river incision, river pattern adjustments, establishment of private and
615 governmental commercial farms and development induced displacements) was analysed and its
616 implication for livelihood resources' availability was assessed. Livelihood strategies were identified and
617 spatially analysed. In the upper Beles area, over 250 people drowned, people lost land (163 ha) and
618 livestock and in general are unhappy with the IBWT. They opt for the business as usual approach,

619 additionally to the uncompensated negative impacts. In the districts of Jawi and Pawe, the
620 development induced resettlement has led to difficult living conditions and forced local people to
621 diversify their economic activities, away from agriculture. The sugar factories are still not operational
622 and in this way fail to provide job opportunities and fail to solve the national sugar shortages. Only
623 near the town of Pawe, local communities intensified their production systems, and shifted towards
624 the smallholder irrigation of 50 ha of land. The irrigable area is limited due to the sugarcane command
625 area. From this analysis, it is clear that for the Tana-Beles project national development goals conflict
626 with local development needs, and are at the expense of rural livelihoods.

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

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

645 **7. ACKNOWLEDGEMENTS**

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

654 **8. REFERENCES**

- 655 Abdelhady, D., Aggestam, K., Andersson, D.-E., Beckman, O., Berndtsson, R., Palmgren, K.B., Madani,
656 K., Ozkirimli, U., Persson, K.M., Pilsjö, P., 2015. The Nile and the Grand Ethiopian Renaissance
657 Dam: Is There a Meeting Point between Nationalism and Hydrosolidarity? *Journal of*
658 *Contemporary Water Research & Education* 155, 73–82.
- 659 Adams, W.M., 1985. The Downstream Impacts of Dam Construction: A Case Study from Nigeria.
660 *Transactions of the Institute of British Geographers* 10, 292–302.
- 661 ADSWE (Amhara Design and Supervision Works Enterprise), 2012. Tana-Beles Integrated Sugar
662 Development Project - Socioeconomic Impact Assessment. Bahir Dar (Ethiopia).
- 663 Alemayehu, T., McCartney, M.P., Kebede, S., 2010. The water resource implications of planned
664 development in the lake Tana catchment, Ethiopia. *Ecohydrology and Hydrobiology* 10, 211–222.
- 665 Archfield, S.A., Vogel, R.M., 2010. Map correlation method: Selection of a reference streamgage to
666 estimate daily streamflow at ungaged catchments. *Water Resources Research* 46, 1–15.
- 667 Arsano, Y., 2007. Ethiopia and the Nile - Dilemmas of National and Regional Hydropolitics.
- 668 Bazin, F., Skinner, J., Koundouno, J., 2011. Sharing the water, sharing the benefits - Lessons from six
669 large dams in West Africa. London (UK).
- 670 Berga, L., Buil, J.M., Bofil, E., De Cea, J.C., Perez, J.G., Mañueci, G., Polimon, J., Soriano, A., Yagüe, J.,
671 2006. Dams and Reservoirs, Societies and Environment in the 21st Century, in: *Proceedings of the*
672 *International Symposium on Dams in the Societies of the 21st Century*. CRC Press, Barcelona
673 (Spain).
- 674 Bergkamp, G., McCartney, M.P., Dugan, P., McNeely, J., Acreman, M.C., 2000. Dams, Ecosystem
675 Functions and Environmental Restoration, *World Commission on Dams Thematic Review*
676 *Environmental Issues II.1*. Cape Town (South Africa).
- 677 Bhattarai, M., Pant, D., Molden, D., 2005. Socio-economics and hydrological impacts of Melamchi
678 intersectoral and interbasin water transfer project, Nepal. *Water Policy* 7, 163–180.
- 679 Biswas, A.K., 2004. Dams: Cornucopia or disaster? *International Journal of Water Resources*

680 Development 20, 3–14.

681 Bosshard, P., 2010. The dam industry, the World Commission on Dams and the HSAF process. *Water*
682 *Alternatives* 3, 58–70.

683 Brandt, S.A., 2000. Classification of geomorphological effects downstream of dams. *Catena* 40, 375–
684 401.

685 Cai, X., 2008. Water stress, water transfer and social equity in Northern China - Implications for policy
686 reforms. *Journal of Environmental Management* 87, 14–25.

687 Church, M., 1995. Geomorphic response to river flow regulation - Case studies and time-scales.
688 *Regulated Rivers-Research & Management* 11, 3–22.

689 Cox, W.E., 1999. Interbasin water transfer, in: UNESCO (Ed.), *Determining When Interbasin Water*
690 *Transfer Is Justified - Criteria for Evaluation*. Paris (France), pp. 173–178.

691 Crewett, W., Korf, B., 2008. Ethiopia: Reforming land tenure. *Review of African Political Economy* 35,
692 203–220.

693 Davies, B.R., Thoms, M., Meador, M., 1992. An assessment of the ecological impacts of interbasin
694 water transfers, and their threats to river basin integrity and conservation. *Aquatic Conservation:*
695 *Marine and Freshwater Ecosystems* 2, 325–349.

696 de Andrade, J.G.P., Barbosa, P.S.F., Souza, L.C.A., Makino, D.L., 2011. Interbasin Water Transfers: The
697 Brazilian Experience and International Case Comparisons. *Water Resources Management* 25,
698 1915–1934.

699 Deininger, K., Ayalew Ali, D., Holden, S., Zevenbergen, J., 2008. Rural Land Certification in Ethiopia:
700 Process, Initial Impact, and Implications for Other African Countries. *World Development* 36,
701 1786–1812.

702 Dessie, M., Verhoest, N.E.C., Pauwels, V.R.N., Adgo, E., Deckers, J., Poesen, J., Nyssen, J., 2015. Water
703 balance of a lake with floodplain buffering: Lake Tana, Blue Nile Basin, Ethiopia. *Journal of*
704 *Hydrology* 522, 174–186.

705 EEPCo, 2011. Beles Multipurpose Project - General Information. Addis Ababa (Ethiopia).

706 Fantini, E., Muluneh, T., Smit, H., 2018. Big projects, strong states? Large scale investments in irrigation
707 and state formation in the Beles valley, Ethiopia, in: Menga, F., Swyngedouw, E. (Eds.), *Water,*
708 *Technology and the Nation-State*. Routledge, Abingdon (UK), p. 248.

709 FDRE (Federal Democratic Republic of Ethiopia), 2011. Ethiopia's Climate-Resilient Green Economy
710 Strategy. Addis Ababa (Ethiopia).

711 FDRE (Federal Democratic Republic of Ethiopia), 2007. Proclamation No. 135/2007 - Payment of
712 compensation for property situated on landholdings expropriated for public purposes. Addis
713 Ababa (Ethiopia).

714 Fedeler, K., 2018. 20th International Convergence of Ethiopian Studies (ICES20), in: *Hydraulic Missions,*
715 *Ruins and Revival: Politics of Space in the Tana-Beles Basin from 1985 to Today*. Mekelle, p. 433.

716 Friedman, J.M., Osterkamp, W.R., Scott, M.L., Auble, G.T., 1998. Downstream effects of dams on
717 channel geometry and bottomland vegetation: Regional patterns in the great plains. *Wetlands*
718 18, 619–633.

719 Friend, P.F., Sinha, R., 1993. Braiding and meandering parameters. *Geological Society Special*
720 *Publications* 75, 105–111.

721 Friis, I., Demissew, S., van Breugel, P. (Eds.), 2010. *Atlas of the Potential Vegetation of Ethiopia*. Det
722 Kongelige Danske Videnskabernes Selskab, Copenhagen (Denmark).

723 Garandeau, R., Edwards, S., Maslin, M., 2014. Biophysical, socioeconomic and geopolitical impacts
724 assessments of large dams: an overview. London (UK).

725 Germanoski, D., Schumm, S.A., 1993. Changes in braided river morphology resulting from aggradation
726 and degradation. *Journal of Geology* 101, 451–466.

727 Getches, D.H., 2005. Water Conservation, Reuse, and Recycling, in: *Interbasin Water Transfers in the*
728 *Western United States - Issues and Lessons*. pp. 233–251.

729 Graf, W.L., 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers.
730 *Geomorphology* 79, 336–360.

731 Gupta, J., van der Zaag, P., 2008. Interbasin water transfers and integrated water resources

732 management: Where engineering, science and politics interlock. *Physics and Chemistry of the*
733 *Earth* 33, 28–40.

734 Hagos, H., Mengistu, L., Mequanint, Y., 2014. Determining Optimum Harvest Age of Sugarcane
735 Varieties on the Newly Establishing Sugar Project in the Tropical Areas of Tendaho, Ethiopia.
736 *Advances in Crop Science and Technology* 2.

737 IHA (International Hydropower Association), 2017. 2017 Hydropower Status Report. London (UK).

738 James, W., 1986. Lifelines: exchange marriage among the Gumuz, in: Donham, D., James, W. (Eds.),
739 *The Southern Marches of Imperial Ethiopia: Essays in History and Social Anthropology*. Cambridge
740 University Press, Cambridge (UK), pp. 119–147.

741 Kamski, B., 2016. The Kuraz Sugar Development Project (KSDP) in Ethiopia: between ‘sweet visions’
742 and mounting challenges. *Journal of Eastern African Studies* 10, 568–580.

743 Kellerhals, R., Church, M., Davies, L.B., 1979. Morphological effects of interbasin river diversions.
744 *Canadian Journal of Civil Engineering* 6, 18–31.

745 Kibler, K., Tullos, D.D., Tilt, B., Magee, D., Foster-Moore, E., Gassert, F., 2012. Integrative Dam
746 Assessment Model (IDAM) Documentation: Users Guide to the IDAM Methodology and a Case
747 Study from Southwestern China. Oregon State University, Corvallis (US).

748 Komakech, H.C., Van der Zaag, P., Van Koppen, B., 2012. The last will be first: Water transfers from
749 agriculture to cities in the Pangani River Basin, Tanzania. *Water Alternatives* 5, 700–720.

750 Kondolf, G.M., 1997. Hungry water: Effects of dams and gravel mining on river channels. *Environmental*
751 *Management* 21, 533–551.

752 Magilligan, F.J., Sneddon, C., Fox, C.A., 2016. The era of big dam building: it ain’t over till it’s over, in:
753 Ashcraft, C.M., Mayer, T. (Eds.), *The Politics of Fresh Water*. Routledge, London (UK), p. 260.

754 Markakis, J., 2011. *Ethiopia: the last two frontiers*. Boydell & Brewer Ltd, Woodbridge (UK).

755 McCartney, M.P., 2007. *Decision Support Systems for Large Dam Planning and Operation in Africa*,
756 Working Paper 119. Colombo (Sri Lanka).

757 McCartney, M.P., Sullivan, C., Acreman, M.C., 2000. *Ecosystem Impacts of Large Dams, Background*

758 Paper Nr. 2 Prepared for IUCN/UNEP/WCD.

759 Mège, D., Korme, T., 2004. Dyke swarm emplacement in the Ethiopian Large Igneous Province: Not
760 only a matter of stress. *Journal of Volcanology and Geothermal Research* 132, 283–310.

761 Mehta, L., 2001. The manufacture of popular perceptions of scarcity: Dams and water-related
762 narratives in Gujarath, India. *World Development* 29, 2025–2041.

763 Michalkova, M., Piégay, H., Kondolf, G.M., Greco, S.E., 2011. Lateral erosion of the Sacramento River,
764 California (1942-1999), and responses of channel and floodplain lake to human influences. *Earth
765 Surface Processes and Landforms* 36, 257–272.

766 NCP (National Contact Point) Italy, 2017. Specific instance submitted to the Italian NCP on March 11,
767 2016 by Survival International Italia against Salini Impregilo S.p.A.

768 Nyssen, J., Fetene, F., Dessie, M., Alemayehu, G., Sewnet, A., Wassie, A., Kibret, M., Walraevens, K.,
769 Nicolai, B., Annys, S., Tegegne, F., Van Passel, S., Frankl, A., Verleyen, E., Teklemariam, D., Adgo,
770 E., 2018. Persistence and changes in the peripheral Beles basin of Ethiopia. *Regional
771 Environmental Change*. <https://doi.org/https://doi.org/10.1007/s10113-018-1346-2>

772 Olivier de Sardan, J.-P., 2005. *Anthropology and Development - Understanding Contemporary Social
773 Change*. Zed Books Ltd., New York (US).

774 Richter, B.D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., Chow, M., 2010. Lost in
775 development's shadow: The downstream human consequences of dams. *Water Alternatives* 3,
776 14–42.

777 Scoones, I., 2009. Livelihoods perspectives and rural development. *Journal of Peasant Studies* 36, 171–
778 196.

779 SMEC, 2008. *Hydrological Study of the Tana-Beles Sub-basins - Ecological Study with Emphasis on
780 Biological Resources*. Brisbane (Australia).

781 Sneddon, C., Harris, L., Dimitrov, R., Özesmi, U., 2002. Contested waters: Conflict, scale, and
782 sustainability in aquatic socioecological systems. *Society and Natural Resources* 15, 663–675.

783 Taukenov, T., Dzhanelieva, K., Yerzhanova, Z., 2018. Methods of improving the efficiency of

784 monitoring of channel deformations of mountain rivers near built-in settlements: on the example
785 of the Buktyrma River. *Geodesy and Cartography* 44, 28–35.

786 Thomas, D.H.L., Adams, W.M., 1999. Adapting to Dams: Agrarian change downstream of the Tiga Dam,
787 Northern Nigeria. *World Development* 27, 919–935.

788 Verhoeven, G., Sevara, C., Karel, W., Ressler, C., Doneus, M., 2013. Undistorting the Past: New
789 Techniques for Orthorectification of Archaeological Aerial Frame Imagery, in: Corsi, C. (Ed.), *Good
790 Practice in Archaeological Diagnostics*. Springer International Publishing, Cham (Germany).

791 Verhoeven, H., 2011. Black Gold for Blue Gold ? Sudan’s oil, Ethiopia’s water and regional integration,
792 Africa Programma. London (UK).

793 WCD (World Commission on Dams), 2000. Dams and Development - A new framework for decision-
794 making. Eartscan Publications Ltd, London (UK).

795 Williams, G.P., Wolman, M.G., 1984. Downstream effects of dams on alluvial rivers, Geological Survey
796 Professional Paper 1286.

797 Wilmsen, B., 2016. After the Deluge: A longitudinal study of resettlement at the Three Gorges Dam,
798 China. *World Development* 84, 41–54.

799 Wolde-Selassie, A., 2004. Gumuz and highland resettlers: differing strategies of livelihood and ethnic
800 relations in Metekel, northwestern Ethiopia. Transaction Publishers, London (UK).

801 Young, W.J., Chessman, B.C., Erskine, W.D., Raadik, T.A., Wimbush, D.J., Tilleard, J., Jakeman, A.J.,
802 Varley, I., Verhoeven, T.J., 2004. Improving expert panel assessments through the use of a
803 composite river condition index - The case of the rivers affected by the Snowy Mountains hydro-
804 electric scheme. *River Research and Applications* 20, 733–750.

805 Zhang, L., Li, S., Loáiciga, H.A., Zhuang, Y., Du, Y., 2015. Opportunities and challenges of interbasin
806 water transfers: a literature review with bibliometric analysis. *Scientometrics* 105, 279–294.

807 Zhang, Q., 2009. The South-to-North Water Transfer Project of China: Environmental implications and
808 monitoring strategy. *Journal of the American Water Resources Association* 45, 1238–1247.

809 Zhuang, W., 2016. Eco-environmental impact of inter-basin water transfer projects: a review.

810 Environmental Science and Pollution Research 23, 12867–12879.

811