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# To What Extent Is Hydrologic Connectivity Taken into Account in Catchment Studies in the Lake Tana Basin, Ethiopia? A Review

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**Abstract:** Knowledge of hydrologic connectivity is important to grasp the hydrological response at a basin scale, particularly as changes in connectivity can have a negative effect on the environment. In the context of a changing climate, being able to predict how changes in connectivity will affect runoff and sediment transport is particularly relevant for land-use planning. Many studies on hydrology, geomorphology and climatology have been conducted in the Lake Tana Basin in Ethiopia, which is undergoing rapid development and significant environmental changes. This systematic literature review aims at assessing to what extent the hydrologic connectivity has been taken into account in such research, and to identify research gaps relevant to land and water management. On the Web of Science and Scopus databases, 135 scientific articles covering those topics were identified. Aspects of hydrologic connectivity were mostly implicitly taken into account based on process-based, statistical and descriptive models. Amongst the drivers of changing connectivity, the climate was covered by a large majority of publications (64%). Components of structural hydrologic connectivity were accounted for by considering geomorphology (54%) and soils (47%), and to a lesser extent, hydrography (16%) and geology (12%). Components of functional connectivity were covered by looking at surface water fluxes (61%), sediment fluxes (18%) and subsurface water fluxes (13%). While numerous studies of the Lake Tana Basin accounted for the hydrologic connectivity implicitly, these related predominantly to functional components. The structural components are given less attention, while in the context of a changing climate, better insights into their influence on the hydrologic seem most relevant. Better knowledge of the static aspect of connectivity is particularly important for targeting appropriate soil and water conservation strategies. Being able to explicitly assess the 'structural connectivity' is therefore of direct relevance for land management and land-use policy.

**Keywords:** hydrology; geomorphology; geology; structural connectivity; functional connectivity

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## 1. Introduction

Hydrologic connectivity is an important topic in climatic, hydrologic and geomorphologic studies, and many studies described the relation between hydrologic connectivity processes and soil erosion, as well as catchment management [1]. The concept of hydrologic connectivity refers to "the material transfer of matter, energy and/or organisms within or between elements of the hydrologic cycle" [2]. In geomorphic systems, investigations of connectivity and dis-connectivity focus on fluxes of different types of materials, such as water [3], sediment [4] and associated substances, as pollutants [5]. In geomorphology and hydrology, connectivity can hence be classified as 'landscape connectivity', 'hydrologic connectivity' and 'sediment connectivity' [1]. Ali and Roy [6] classified hydrologic connectivity in several definitions, which either focus on water cycle [2], landscape features at the catchment scale [1,7], landscape features in hillslope scale [8], spatial patterns of catchment properties i.e., permeability and soil moisture [9], and flow processes at hillslope scale [10].

The majority of hydrologic connectivity research focuses on connectivity indices, modeling and a conceptual framework [11]. For example, Borselli, et al. [12] developed the Index of Connectivity (IC) and Field Index of Connectivity (FIC). The IC is a GIS-based metric that can be used to represent the characteristics of the watershed under evaluation, particularly the potential connectivity between different parts of the catchment. The FIC was developed using actual field measurements of connected flow channels acquired as quickly as feasible after an event, and defined by field assessment [12]. Ali and Roy [13] also assessed the index of connectivity and argued that the way a connectivity metric is developed affects how well it captures critical spatial organization in soil moisture patterns. Therefore, they investigated a wide range of 2-D and 3-D connectivity measures based on quasi-continuous soil moisture patterns. The output of the connectivity assessment varied depending on the computed metric. Models of hydrologic connectivity are used to investigate the factors that influence the development of flow connections as topographic features change [3,14,15]. A few spatially distributed hydrological models have been explicitly designed to predict or explore how connectivity might change alongside the catchment and climate change [3]. While the conceptual frameworks studied by Bracken and Croke [1] and Keesstra, et al. [16] introduce a connectivity framework that evaluates some of the most important elements that influence the physical linking of water, and indirectly, sediment, in catchments. Bracken and Croke [1] categorized hydrologic connectivity as either static or dynamic variables. The 'static' or 'structural connectivity' refers to the spatial pattern of state variables that influence flow path and water transfer patterns in hydrologic systems, while 'dynamic' or 'functional connectivity' relates to the interaction between spatial patterns of catchment properties and processes that generate runoff and water transfer [3,17]. In the field of hydrology, static or structural connectivity can be calculated using contiguity indices such as flow length [18], whereas the dynamic or functional connectivity is evaluated with solute or water flow and the time to travel across the landscape [19]. The latter is often more challenging to assess [3,20].

Climate variability, tectonics, fire regimes, land use and water management are all factors that influence hydrologic connectivity [16]. Climate is the factor that mainly controls the spatiotemporal patterns of runoff distribution and sediment export [1], whereby the amount and timing of rainfall is particularly important [21]. Seasonal rainfall patterns have a major impact on connectivity related to soil moisture patterns, especially during the wet season [22]. Rainfall is the prime factor influencing discharge (water fluxes), sediment yield (sediment fluxes), geochemical fluxes and land and water management fluxes. Similarly, Garbin, et al. [23] described that rainfall intensity, frequency and amount are the main drivers of streamflow/runoff generation, and are thus likely to have an effect on hydrologic connectivity. In addition to climatological aspects, static and dynamic connectivity are limited, and enhanced by biotic aspects [24] and human activities due to different land-use practices and land cover change [25]. Vegetation patterns impact connectivity, as grasslands, bushlands and forests can minimize the raindrop impact, increase the infiltration capacity and enhance soil development [16]. On the other hand, land-use change caused by human intervention also greatly impacts catchment characteristics, and therefore impacts runoff and functional connectivity [26–28]. In contrast, soil water conservation measures, ploughing and hydraulic infrastructures decrease connectivity [2,16,25]. Dams and water gates modify stream flow and change the river ecosystem [29].

Hydrologic connectivity is mostly studied using hydrological and geomorphological models, consisting of process-based, statistical, cellular automata and GIS approaches [30]. These models can be used to know how static (system phase) and dynamic (system fluxes) components of connectivity interact. The interaction between static and dynamic components show the influence of water, sediment, biota and chemical flows on the evolution and fluctuation of the system without changing the boundary conditions. In certain cases, the equilibrium state can change without the influence of external forces, but the internal dynamics consequently force the system into a different equilibrium [16]. Taking hydrologic connectivity into account is important to better understand the impacts of the system changes, and provide knowledge and important information to decision-makers [20]. Hydrologic connectivity in a catchment in a context-specific basis can be understood by an approach based on field knowledge, where both functional and structural aspects of connectivity are considered [20]. The application of a conceptual framework will help identifying static (structural) aspects and dynamic (functional) aspects of connectivity.

Drawing on the conceptual framework presented by Keesstra, et al. [16], we review the literature covering hydrologic and geomorphic characteristics and processes of the Lake Tana Basin in northern Ethiopia. The Lake Tana Basin faces environmental problems such as land degradation, soil erosion and water pollution, partly linked to climate change [31], LULC change [31,32], high population growth and poor conservation systems [32]. Bogale, et al. [33] stated that land degradation is triggered by inappropriate land use and management. Moreover, land use and land cover change modify the hydrological regime of the catchment [34]. Soil and water conservation treatments in the catchment can change the runoff ratio [35]. The numerous environmental problems in the Lake Tana basin have attracted many studies.

Being the headwaters of the Blue Nile, over the last decades the Lake Tana Basin in north-western Ethiopia was the focus of many studies in the domain of climate, hydrology, geomorphology, soil erosion, sediment transport, land-use/land-cover change and water management. By making a systematic review of this body of literature, the aims of this study were to have an overview of the issues that determine the hydrologic connectivity, which have been well covered, and reciprocally, to identify issues that would deserve more research. Therefore, the specific objectives were to analyze to which extent hydrologic connectivity has been taken into account in research in the Lake Tana Basin, and which of the elements of hydrologic connectivity had been covered, or had apparently been neglected. Five research questions are addressed in this review:

1. Has hydrologic connectivity been taken into account, and what are the main research gaps related to hydrologic connectivity?
2. How is the effect of climate, land use and land-water management on hydrological response taken into account?
3. What is the relative influence of structural connectivity on runoff response?
4. What kind of models were used in connectivity studies, and what are the implications posed by the different kind of models?
5. How has the connection between structural and functional connectivity of hydrologic connectivity been taken into account?

The connectivity concepts proposed by Keesstra, et al. [16] proved to be particularly useful for this literature review. Furthermore, from the review it emerges that dynamic aspects of connectivity are better accounted for than static aspects. We will argue that better knowledge of the static aspects of connectivity is crucial for targeting soil and water conservation strategies that are appropriate for particular areas.

## 2. Materials and Methods

The Lake Tana Basin is very dynamic due to both natural and human activities. The basin covers an area of 15,114 km$^2$ with a 3111 km$^2$ lake surface, which makes Lake Tana the largest freshwater resource in Ethiopia [36]. Lake Tana has four major tributaries: the Gilgel Abay, the Gumara, the Rib and the Megech rivers, which contribute to approximately 95% of the annual inflow to the lake [37]. The Gilgel Abay subbasin is the largest of these, and drains 35% of the basin; the Megech drains 8% of the basin, and the Gumara and Rib each drain 26% of the basin. Additionally, there are some smaller catchments, and some areas drain directly towards the lake.

This literature search was done in April 2021, using the scientific databases Web of Science and Scopus. The first stage of systematic review is determining the keywords that are used in the search procedure. The search keywords which are relevant to the Lake Tana Basin are (“lake tana” AND (hydrology OR geomorphology OR climate OR “land use” OR “land cover” OR soil OR streamflow OR “water flow” OR “sediment flow” OR "hydrologic connectivity"). The second stage is the selection process, consisting of two phases: removing duplicates and screening the title and abstract to make sure that the publications are not out of topic. The duplicates were removed, resulting in 288 publications. Furthermore, based on the selection criteria, a total of 153 papers were removed. For the article selection, the criteria that were used were language, region, type of literature and topic (Table 1). In the third stage, the papers were systematically reviewed (Figure 1).

**Table 1.** The article selection criteria.

| Criteria | Inclusion | Exclusion |
|---|---|---|
| Language | English | Non-English |
| Region | Lake Tana Basin and its subbasin, and as part of the Upper Blue Nile Basin | Outside Lake Tana Basin/Upper Blue Nile Basin |
| Type of Literature | Peer-reviewed journal articles | Book, book chapter, conference proceeding, review paper |
| Topic | Research articles journals related to physical geography studies (hydrology, geomorphology, climatology) | All other studies |

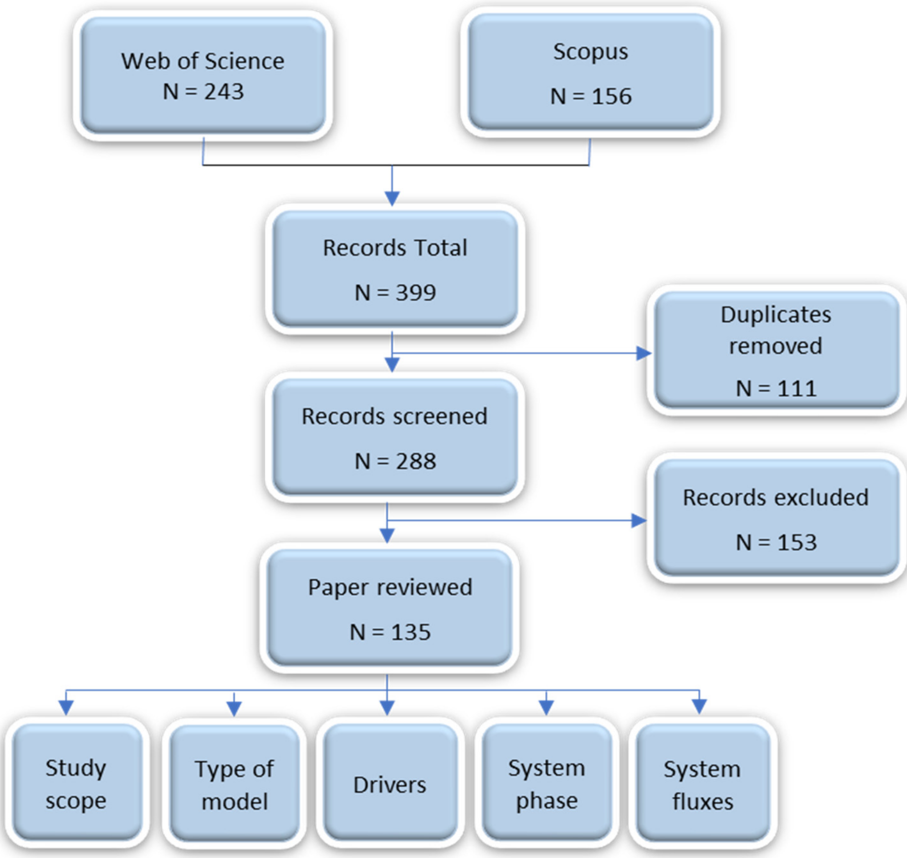


**Figure 1.** Flow diagram of the process of systematic review.

A database was constructed with information on the authors, journal title, year of publishing and study site, specific subject of the paper, materials and methods used, general findings and information related to hydrologic connectivity. The conceptual framework of Keesstra, et al. [16] was used to analyze aspects of connectivity (drivers, system phase and system fluxes). The papers were analyzed by focusing on five specific topics (Table 2). Qualitative attributes were expressed as one (1), which means the paper reported one aspect of connectivity, or zero (0), which means the aspect of connectivity was not considered in the research.

**Table 2.** Topic of focus considered to classify and analyze the 135 research papers relating to climate, hydrology and geomorphology of the Lake Tana Basin.

| Topic of Focus | Qualitative Attributes |
|---|---|
| Study scope | Plot/field, subbasin, basin, lake |
| Type of model | Descriptive/conceptual, statistical, empirical, process-based |
| Drivers of connectivity | Climate, LULC/change, land and water management, tectonic, fire regimes |
| System phase (static aspects of connectivity) | Geology, geomorphology, soil, hydrology |
| System fluxes (dynamic aspect of connectivity) | Water fluxes, sediment fluxes, biota fluxes, geochemical fluxes, land and water management fluxes |

## 3. Results

### *3.1. Spatial Scope*

More than half (54%) of the 135 reviewed publications reported on research conducted in one or several of the subbasins of the Lake Tana Basin. About one-third (34%) looked at the whole Lake Tana Basin, or considered it as part of the Upper Blue Nile Basin. Some papers (7%) were concerned with Lake Tana itself, while even fewer (4%) reported on studies conducted at plot or field levels (Figure 2). The spatial scale of the study affects the method of data acquisition. Plot scale or small catchment used field/measurement data, while basin and subbasin tend to use secondary data and modelled data. Plot scales were applied in studies with short-term datasets, whereas basin/subbasin scales were used with long-term datasets.

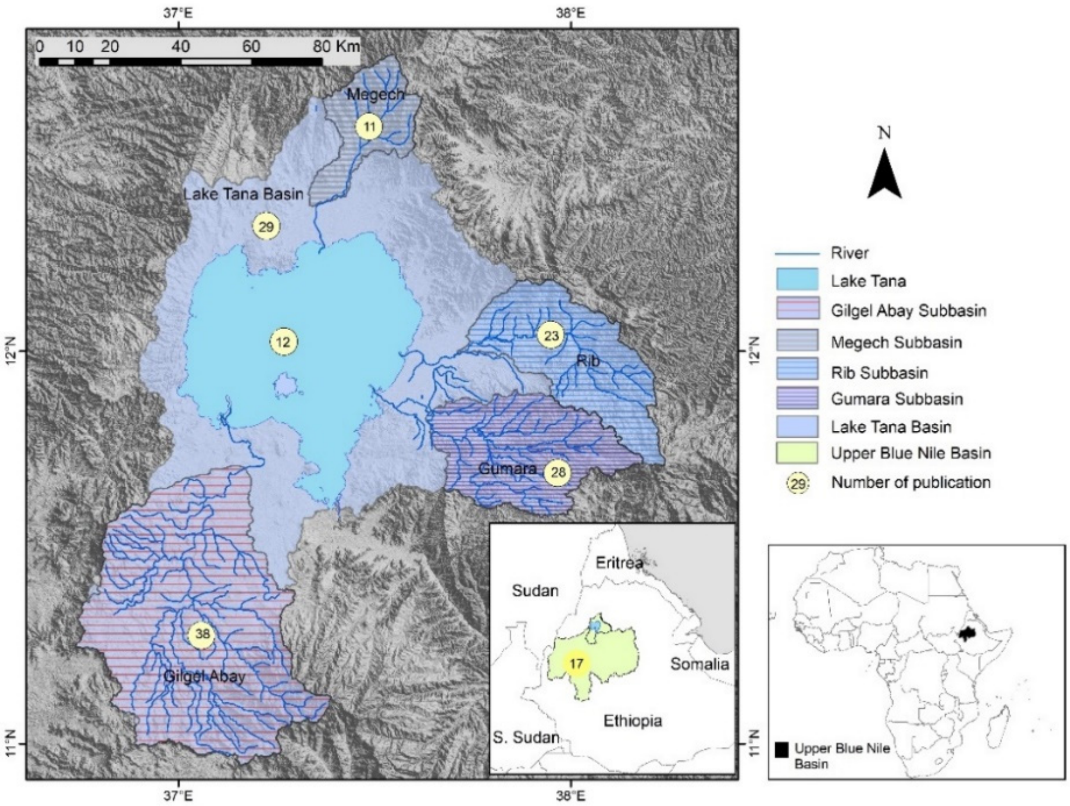


**Figure 2.** Number of publications in the domain of climate, hydrology and geomorphology of the Lake Tana Basin according to the spatial scope covered. One study can appear in more than one subbasin.

### 3.2. *Assessment Connectivity in the Lake Tana Basin*

In the majority (63%) of publications, hydrologic connectivity is taken implicitly into account. These rely on semi-distributed models, statistical models and descriptive models to assess water, sediment, geochemical and land and water management fluxes as proxies (Table 3). Only one publication (0.7%) assessed connectivity explicitly. Geremew and Triest [38] evaluated how hydrologic connectivity and vegetative dispersal affected the clonal and genetic structure of *Cyperus papyrus* populations in Lake Tana. The remaining publications (36.3%) only focused on one aspect of the hydro-geomorphological system.

**Table 3.** Assessment connectivity using the implicit approach in the Lake Tana Basin.

| Drivers | System Fluxes | Model | References |
|---|---|---|---|
| Climate | Surface flow | HBV | Abdo, et al. [39]; Haile, et al. [40]; Asitatikie and Gebeyehu [41]; Habib, et al. [42]; Worqlul, et al. [43]; Worqlul, et al. [44] |
| | | SWAT | Dile, et al. [45]; Robi, et al. [46]; Roth, et al. [47]; Chakilu, et al. [48]; Setegn, et al. [49]; Ali, et al. [50]; Ayana, et al. [51]; Ayele, et al. [52]; Dessie, et al. [53]; Duan, et al. [54]; Tegegne, et al. [55]; Tigabu, et al. [56]; Wagena, et al. [57]; Worqlul, et al. [58]; Setegn, et al. [59]; Tegegne and Kim [60]; Moges, et al. [61] |
| | | A physical-based GWLF | Ayele, et al. [62] |
| | | VHM and NAM | Taye, et al. [63] |
| | Subsurface flow | SWAT | Setegn, et al. [49]; Worqlul, et al. [58], Tigabu, et al. [64] |
| | Sediment flow | SWAT | Ayana, et al. [65]; Woldesenbet, et al. [66]; Berihun, et al. [67]; Lemma, et al. [68]; Ali, et al. [50]; Ayele, et al. [52]; Wagena, et al. [57] |
| | Geochemical flow | Statistical Model | Moges, et al. [61]; Alemu, et al. [69] |
| Land use-land cover | Surface flow | SWAT | Woldesenbet, et al. [66]; Tigabu, et al. [64]; Teklay, et al. [70]; Tikuye, et al. [71] |
| | | TOPMODEL | Gumindoga, et al. [72] |
| | | HBV | Birhanu, et al. [73] |
| | Subsurface flow | SWAT | Woldesenbet, et al. [74]; Tigabu, et al. [64]; Woldesenbet, et al. [66]; Tikuye, et al. [71] |
| | Land and water management flow | Descriptive/Conceptual Model | Addisu, et al. [75] |
| | Sediment flow | SWAT | Addis, et al. [76]; Woldesenbet, et al. [66]; Berihun, et al. [67] |
| Land and water management | Surface flow | SWAT | Andualem, et al. [77]; Tigabu, et al. [64]; Melaku, et al. [78] |
| | | Statistical Model | Weldegebriel, et al. [35]; Monsieurs, et al. [79]; Akale, et al. [80] |
| | Subsurface flow | Statistical Model | Adem, et al. [81]; Akale, et al. [80] |
| | Sediment flow | SWAT | Andualem, et al. [77]; Melaku, et al. [78]; Lemma, et al. [68] |
| | Land and water management flow | | Abera, et al. [82] |

### 3.3. *Drivers, Static, Dynamic Aspect of Connectivity*

The majority of publications covered climate characteristics/change (64%), land-use/land-cover change (52%) and land-water management that relate to hydrologic connectivity (Figure 3). Some publications focused on rainfall intensity and variability, which are obvious drivers of connectivity, whereas others took into account the impact of climate change on the future hydrological response (mainly surface water flows).

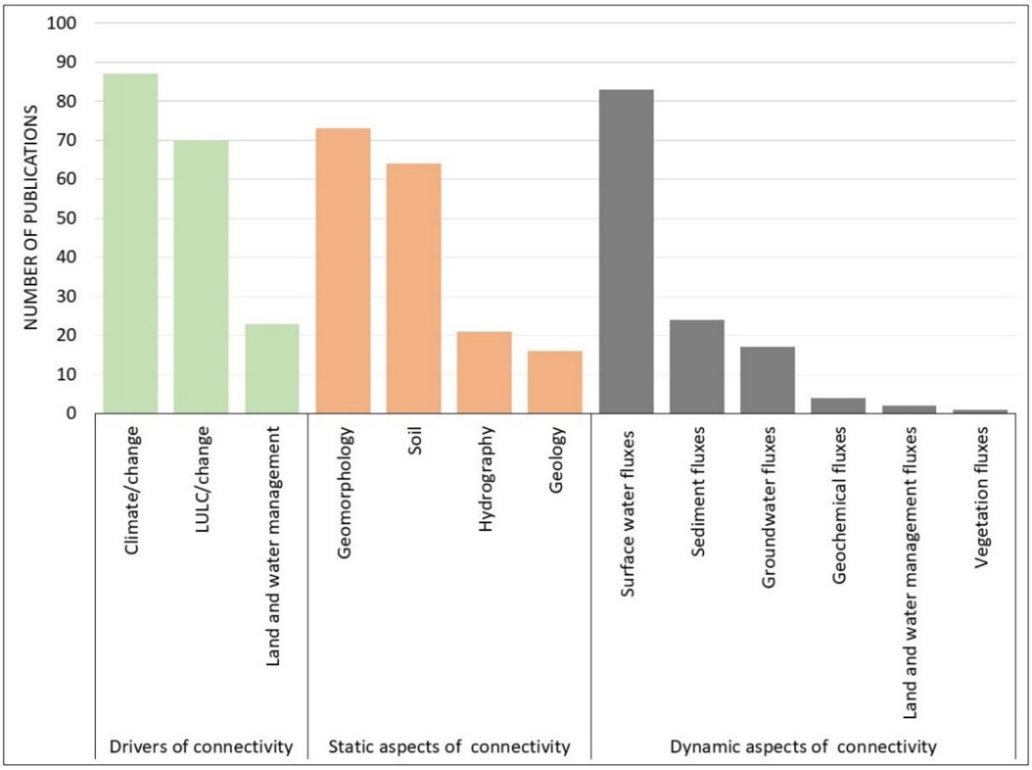


**Figure 3.** Number of publications addressing aspects of hydrologic connectivity, based on the concepts proposed by Keesstra, et al. [16].

The impact of climate change on surface water fluxes was studied using baseline data and future prediction, whereby some assume a wetter future by 2070–2100 [45], 2041–2070 [63], and others a drier future by 2071–2099 [39], 2010–2040 [45], 2041–2070 [40], and 2080–2100 [49]. However, only a few studies have shown the impact of rainfall changes on subsurface or groundwater flow. Only Setegn, et al. [49] describes that climate change will reduce groundwater flow for all downscaled models. Tigabu, et al. [83] studied the impact of rainfall variability on the groundwater head, and found that the peak of the groundwater head occurs one to three months after the peak of the rainfall. Nigate, et al. [84] described how the average annual groundwater recharge calculated using the SMB approach for the five years (2012–2016) is 748 mm, or 51% of the rainfall.

Land-use/land cover (LULC) and LULC changes have a significant impact on hydrologic connectivity [3]. Most land-use change analyses were carried out using historical data, but there was one study that predicted LULC changes [71]. Woldesenbet, et al. [66] and Teklay, et al. [70] studied the impact of LULC change on hydrological behavior, and found that the increase in surface runoff and the decrease in groundwater are mostly caused by the increase in farmland and the decrease in woody shrubs and forest. The expanding agricultural land and reducing forest cover also increased peak flow and decreased evapotranspiration, while shrubland expansion reduced surface runoff and increased evapotranspiration [70]. Lemma, et al. [85] investigated sediment yield in the Lake Tana Basin, and found that suspended sediment concentration (SSC) and sediment yield (SY) are typically higher at the start of the rainfed cropping calendar (May–June). By September and October, at the end of the rainfed cropping calendar, SY goes down. Moges and Bhat [86] evaluated the impact of LULC/change on soil erosion, and noticed that most of the severe soil erosion in the watershed was caused by the widespread conversion of grassland and shrubland into agricultural land. Moreover, Frankl, et al. [87] found that the disappearance of woody vegetation has been accompanied by the formation of gully networks and the proliferation of gully heads.

Land and water management includes soil and water conservation practices (SWC) and reservoir constructions, which also have a significant impact on hydrological processes. Soil and water conservation (SWC) decreased surface runoff [80,88] and sediment concentration [80]. Furthermore, Akale, et al. [80] noticed that conservation practices increased baseflow by 45% in Guale and 81% in Tikur-Wuha. Weldegebriel, et al. [35] also looked at the fact that watersheds with more SWC treatments had less storm runoff.

In general, static systems were taken into account as input data for studies. However, there were several publications that examined the static system as a result of the study. For example, Ebabu, et al. [89] presented a significant difference in soil properties among different land use and soil land management practices, while Wubie and Assen [90] and Tamene, et al. [91] showed that land use and land cover change and slope gradient have an impact on soil quality. In the system phase, geology is a static component that was less used in studies in the Lake Tana basin. Several studies used geology as input data to assess groundwater conditions such as lithology and geological structure. Soil was often used, and more than 73 studies used geomorphology (topography, slope gradient) as a static variable. The drivers, static and dynamic variables of connectivity can be seen in Figure 3.

### 3.4. Modelling Approaches of Studies in the Lake Tana Basin

Figure 4 shows the types of models that were used in the research in the Lake Tana Basin. Modelling and statistical analyses are essential for analyzing the temporal and spatial variability of water resources [92,93]. However, the application of hydrological models such as the Soil and Water Assessment Tool (SWAT) and the Hydrological Byrans Vattenbalansavdelning (HVB) requires advances in the availability of both temporal and spatial data. Some studies in the Lake Tana basin used hydrological model to evaluate the impact of climate/change, LULC/change and land and water management.

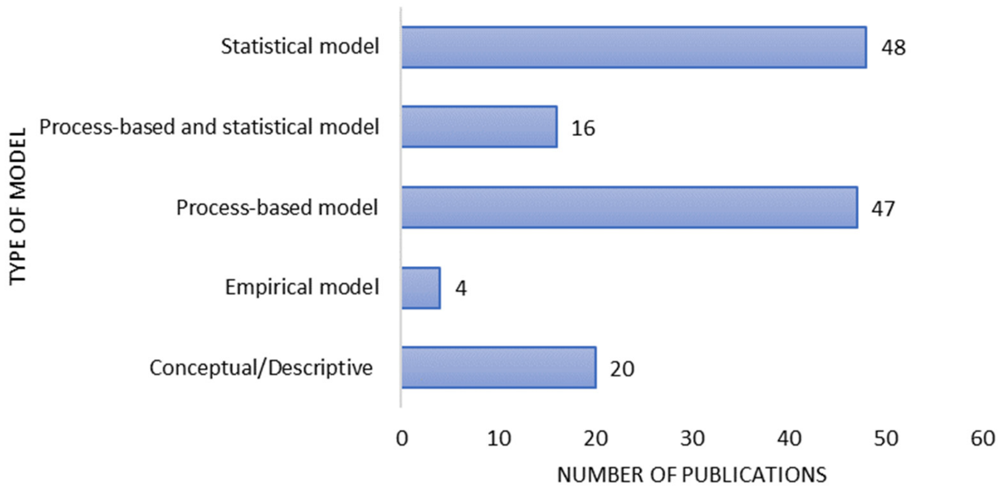


**Figure 4.** Types of modelling approach used in the studies in the Lake Tana basin.

The most widely applied hydrological model in the Lake Tana basin was SWAT, which was used for hydrological response analysis (Figure 5). Some studies used SWAT to evaluate the effect of rainfall on: (1) surface flow, e.g., [45,48,51,53–55,60,61]; (2) surface flow and subsurface flow, e.g., [58,59,83]; (3) surface flow and sediment flow, e.g., [50,57,68]; (4) sediment flow, e.g., [65,94]; (5) lake level, e.g., [95]; (6) drainage ratio, e.g., [96]; (7) soil erosion, e.g., [97]; and (8) flood hazard, e.g., [46]. Other studies used SWAT to analyze the impact of soil and water conservation measured on (1) surface flow and subsurface flow, e.g., [64], and (2) surface flow and sediment flow, e.g., [68,76,78]. Only few studies used SWAT to quantify the impact of land use/land cover on (1) surface flow, e.g., [70], and (2) surface flow and subsurface flow, e.g., [66,71]. Moreover, Polanco, et al. [98] examined the SWAT model performance. Around 12 publications used SWAT and combined it with other hydrological models (MIKE, MODFLOW, PED and HBV). For example, Robi, et al. [46] used SWAT and MIKE FLOOD to analyze the consequences of climate change on streamflow and map the flood hazard in the Ribb watershed. Furthermore, 12 studies used the HBV model to analyze: (1) the impact of rainfall on surface flow/streamflow/inflow, e.g., [39–44,99,100]; (2) the impact of land use/land cover on surface flow, e.g., [73]; and the contribution of ungauged catchment to the lake's water balance, e.g., [101]. MODFLOW, PED and WEAP were also used in a few studies in the Lake Tana basin. PED was used to predict sediment, e.g., [102,103] and phosphor transport [103], while MODFLOW was employed to analyze subsurface flow, e.g., [104,105]. Furthermore, the WEAP model was used to quantify water resources, e.g., [106]. Other models, such as the VHM and the NAM models, for instance, were applied to assess the impact of climate change on hydrological extremes in the Nile River Basin [63].

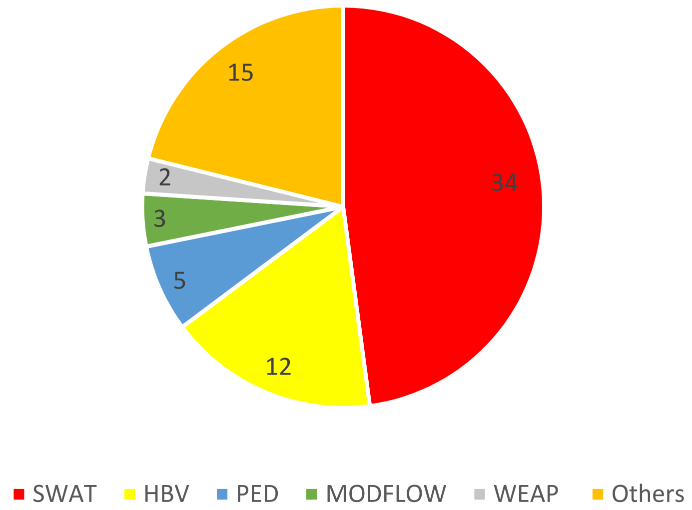


**Figure 5.** Types of hydrological models used in the Lake Tana Basin.

Statistical analysis has been applied in the Lake Tana basin to analyze rainfall data products, rainfall trends and rainfall variability, e.g., [107–122]. Several studies also employed statistical analysis to assess the impact of land use/change, e.g., [64,70,89,90,100,123–125]. Statistical analysis was employed in the Lake Tana basin to assess the impact of land and water management on hydrological processes [35,64,79,80]. In some publications, statistical models were used to assess: (1) the trend of rainfall and runoff, e.g., [126,127]; (2) groundwater recharge, e.g., [84]; (3) soil erosion, e.g., [128]; (4) lake level, e.g., [56,129–131]; (5) phosphorus/dynamic, e.g., [132,133]; (6) sediment, e.g., [134–136]; (7) streamflow, e.g., [100,137]; and (8) water balance [138]. Statistical models were used to the address the hydrological response at the basin, subbasin and plot scale. In 15% of publications on the Lake Tana Basin, the descriptive approach was used to describe: (1) the geomorphology and geomorphological processes, e.g., [139–142]; (2) land-use/land-cover/changes, e.g., [87,143]; (3) groundwater potential, e.g., [144–146]; (4) hydrologic connectivity, e.g., [38]; (5) land and water management and its impact, e.g., [147]; (6) land suitability for irrigation, e.g., [75,148]; (7) land-use/land-cover impact, e.g., [149]; (8) soil erosion, e.g., [150]; (9) water balance, e.g., [151,152]; (10) prioritized sub watershed based on morphometry aspects, e.g., [153]; and (11) hydro-climatic processes, e.g., [154]. Empirical models were used to assess soil erosion, e.g., [86,155–157].

## 4. Discussion

Most publications on the Lake Tana Basin studied hydrologic connectivity implicitly by using discharge and suspended sediment yield (SSY) as proxies for connectivity. Some researchers used semi-distributed models (e.g., SWAT, HBV) to represent connectivity, although they did not use the term of 'connectivity' in their publications. The choice of the hydrological model used may depend on the character of the water resources management issues (temporal and spatial scale) and the scale of physical characteristics variability (land cover, topography, geology). Data quality and availability, model availability and cost can also be a consideration when choosing a suitable model [158].

SWAT is the most commonly used semi-distributed model to evaluate fluxes, for instance to assess the impacts of land cover and land management on water, sediment and chemical fluxes for a wide variety of catchment sizes, land uses and physiography in the Lake Tana Basin. Additionally, SWAT is used to assess the impacts of climate change on hydrological response. Some process-based models, such as semi-distributed models, are better than statistical and empirical models to explain connectivity implicitly, as they can account for small-scale structures and processes over wide areas. In this way, how various landscape elements are connected can be better revealed [159] so that these models are used widely in the Lake Tana Basin. In contrast, only a few studies explicitly looked at hydrologic connectivity due to a lack of data. The ever-increasing accessibility of high-resolution topographic data could help to account for connectivity explicitly [159].

This review illustrates that the three aspects of connectivity aspects Keesstra, et al. [16] put forward were adequately studied in the Lake Tana Basin. The variability of drivers such as climate (rainfall change and variability), land-use/land-cover change, as well as land and water management, affect static and dynamic aspects of connectivity. Rainfall is a primary driver of the variability and availability of streamflow, and therefore strongly affects hydrologic connectivity. Hydrologic connectivity typically rises by increasing rainfall, and is sensitive to even small rainfall changes. From a connectivity perspective, changes in land use and or vegetation have an impact on hydrological response and connectivity within catchments. In general, land-use change in the Lake Tana Basin, particularly the expansion of agricultural land, increased surface runoff and sediment yield. However, soil and water conservation measures tend to reduce surface flow and sediment yield. In other words, land use can increase hydrologic connectivity, while soil and water conservation practices can decrease it. Furthermore, static aspects such as hydrology (water pathways) and geomorphology are highly influential in how a watershed responds. Cavalli, et al. [160] stated that large connectivity variations occur in cases of complex and rugged topography. Moreover, Mishra, et al. [161] evaluated that connectivity in different catchments is controlled by slope gradient. Lane, et al. [162] found that a static description of the topographic structure can be used to generalize a large part of the averaged spatial variation in connectivity over time. However, there are only a few studies in the Lake Tana Basin that consider the effect of static aspects on hydrological response. Therefore, the results of this review reveal knowledge gaps in this area, which underlines how static aspects such as water channel and topography can affect hydrological response and hydrologic connectivity in the Lake Tana Basin.

Geology is also one of the static aspects of connectivity, and is the most important aspect that affects the dynamic aspects of connectivity. However, only few researchers, such as Walker, et al. [163], studied the influence of geology on groundwater, and they established that the deep groundwater within fractured and scoriaceous zones of basalt is not connected to shallow groundwater. These authors also revealed that shallow groundwater flow paths are not always parallel to surface water flow paths. Additionally, Adem, et al. [81] found that in the Gomit subbasin, 30% of the precipitation is drained through faults to an adjacent basin. The findings of the present study point to a lack of knowledge regarding how geology (lithology and geology structure) can affect surface water and groundwater. For this reason, more studies are necessary to investigate the influence of geology on surface water and groundwater, including the emergence of springs that can supply surface water, as well as infiltration capacity variation in relation to geology, geomorphology and soil.

The description and understanding of the system phase (the static system) are the basis for understanding the structural connectivity [20], while understanding the system fluxes (the dynamic system) is important for defining the functional hydrologic connectivity. The close connection and ensuing interactions between system fluxes and the system phase can be appreciated by studying the effects of hydrologic processes on the static components of connectivity. For example, the interactions between rainfall and surface runoff have an impact on the system's static aspect by changing its characteristics, e.g., the topography and the soil depth and the development of connected flow-paths such as gullies. These interactions influence the dynamic processes, as the change in the static aspect will set new conditions for connectivity, which will in turn affect the static element of the landscape. In the Lake Tana Basin, Abate, et al. [140] indicate that the landscape response to changing drivers is visible and observable in deltas and floodplains. They found that the growth of the delta was roughly linear and in the last 30 years, the concentration of sediment in the river had increased twofold. More sediments are trapped in the floodplain due to rising lake levels, rising river beds and farmers modifying the river's course close to the shore.

On the other hand, the interaction between the driver (e.g., rainfall) and the static aspect of connectivity (e.g., geology, topography) can also affect the dynamic aspect of connectivity (e.g., surface flow and groundwater flow). For example, Abiye and Kebede [144] reveal that the diverse geological environment, characterized by variation in lithology and tectonic structures, as well as spatial variation in rainfall, primarily governs the groundwater potential of the Upper Blue Nile River Basin. Moreover, as a result of orographic precipitation and the area's rugged topography, the recharge mechanism is of the mountain-front recharge type, where groundwater moves into alluvial aquifers and fractures. Another example is the interaction between rainfall and flow-paths (gully) that can impact surface runoff, with this review showing that little attention has been given to this topic. In basic terms, the interaction between system phases and system fluxes shows how the state of the system co-evolves and fluctuates as a result of fluxes of water, sediment and biota, and how it is affected by vegetation, geochemical and land and water management within the systems' boundary conditions [16]. Better knowledge of the static aspect of connectivity is of particular importance for soil and water conservation strategies. For example, working in Tanzania, Kabanza, et al. [164] showed that the effectiveness of identical soil conservation measures can strongly vary across different landscape units. Similarly, Achten, et al. [165] showed that the topographic thresholds for the initiation of gully erosion is also strongly dependent on the geomorphologic setting. Moreover, Akale, et al. [80] found that soil and water conservation practices intended to increase infiltration were most effective in the gentle subbasin with deep soil, as they were able to store the infiltrated water for a longer period of time after the rainy season. Hence, whereas 'structural connectivity' can implicitly be accounted for in a black-box fashion in hydrologic models at basin level, being able to explicitly assess its role in connectivity is of direct relevance for land management and land-use policy both within basins and across different basins.

## 5. Conclusions

The systematic literature review has highlighted how hydrologic connectivity is taken into account in the research in the Lake Tana Basin. Most research was conducted at the subbasin scale, and some at the plot scale. Several studies were designed to assess the impact of climate variability and climate change, land-use/land-cover change, soil and water conservation measures on hydrological response and soil erosion. Other studies tend to focus on one aspect, such as climate, geomorphology and land use. Based on 135 studies in the Lake Tana Basin, implicit connectivity is mainly related to research on hydrological response using process-based and statistical models. This review article also identified several research gaps:

1. More attention has been given to climate variability and climate change and land-use/land-cover change, while little attention has been paid to assess the importance of the static aspect of connectivity on hydrological response and hydrologic connectivity.
2. Static aspects of connectivity, such as geology and geomorphology, which affect variation in the water infiltration capacity, as well as the emergence of springs, have received little attention, even though they determine important parameters for hydrological modelling.

3. At the basin level, the impact of soil and water conservation measures has hardly been studied, nor has the contribution of gully erosion been taken into account in hydrologic and sediment modelling.

It is argued that better knowledge of the static aspects of connectivity is particularly important for developing appropriate soil and water conservation strategies.

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## References

1. Bracken, L.J.; Croke, J. The concept of hydrological connectivity and its contribution to understanding runoff-dominated geomorphic systems. *Hydrol. Process.* **2007**, *21*, 1749–1763. [CrossRef]
2. Pringle, C. What is hydrologic connectivity and why is it ecologically important? *Hydrol. Process.* **2003**, *17*, 2685–2689. [CrossRef]
3. Bracken, L.J.; Wainwright, J.; Ali, G.A.; Tetzlaff, D.; Smith, M.W.; Reaney, S.M.; Roy, A.G. Concepts of hydrological connectivity: Research approaches, Pathways and future agendas. *Earth-Sci. Rev.* **2013**, *119*, 17–34. [CrossRef]
4. Bracken, L.J.; Turnbull, L.; Wainwright, J.; Bogaart, P. Sediment connectivity: A framework for understanding sediment transfer at multiple scales. *Earth Surf. Process. Landf.* **2015**, *40*, 177–188. [CrossRef]
5. Masselink, R.J.H.; Heckmann, T.; Temme, A.J.A.M.; Anders, N.S.; Gooren, H.P.A.; Keesstra, S.D. A network theory approach for a better understanding of overland flow connectivity. *Hydrol. Process.* **2017**, *31*, 207–220. [CrossRef]
6. Ali, G.A.; Roy, A.G. Revisiting hydrologic sampling strategies for an accurate assessment of hydrologic connectivity in humid temperate systems. *Geogr. Compass* **2009**, *3*, 350–374. [CrossRef]
7. Tetzlaff, D.; Bacon, P.J.; Youngson, A.F.; Gibbins, C.; Malcolm, I.A. Connectivity between landscapes and riverscapes—A unifying theme in integrating hydrology and ecology in catchment science? *Hydrol. Process.* **2007**, *21*, 1385–1389. [CrossRef]
8. Stieglitz, M.; Shaman, J.; McNamara, J.; Engel, V.; Shanley, J.; Kling, G.W. An approach to understanding hydrologic connectivity on the hillslope and the implications for nutrient transport. *Glob. Biogeochem. Cycles* **2003**, *17*, 1105. [CrossRef]
9. Western, A.W.; Blöschl, G.; Grayson, R.B. Toward capturing hydrologically significant connectivity in spatial patterns. *Water Resour. Res.* **2001**, *37*, 83–97. [CrossRef]
10. Ocampo, C.J.; Sivapalan, M.; Oldham, C. Hydrological connectivity of upland-riparian zones in agricultural catchments: Implications for runoff generation and nitrate transport. *J. Hydrol.* **2006**, *331*, 643–658. [CrossRef]
11. Masselink, R.J.H.; Keesstra, S.D.; Temme, A.J.A.M.; Seeger, M.; Giménez, R.; Casalí, J. Modelling Discharge and Sediment Yield at Catchment Scale Using Connectivity Components. *Land Degrad. Dev.* **2016**, *27*, 933–945. [CrossRef]
12. Borselli, L.; Cassi, P.; Torri, D. Prolegomena to sediment and flow connectivity in the landscape: A GIS and field numerical assessment. *Catena* **2008**, *75*, 268–277. [CrossRef]
13. Ali, G.A.; Roy, A.G. Shopping for hydrologically representative connectivity metrics in a humid temperate forested catchment. *Water Resour. Res.* **2010**, *46*, 1–24. [CrossRef]
14. Meerkerk, A.L.; Van Wesemael, B.; Bellin, N. Application of connectivity theory to model the impact of terrace failure on runoff in semi-arid catchments. *Hydrol. Process.* **2009**, *23*, 2792–2803. [CrossRef]
15. Callow, J.N.; Smettem, K.R.J. The effect of farm dams and constructed banks on hydrologic connectivity and runoff estimation in agricultural landscapes. *Environ. Model. Softw.* **2009**, *24*, 959–968. [CrossRef]
16. Keesstra, S.; Nunes, J.P.; Saco, P.; Parsons, T.; Poeppl, R.; Masselink, R.; Cerdà, A. The way forward: Can connectivity be useful to design better measuring and modelling schemes for water and sediment dynamics? *Sci. Total Environ.* **2018**, *644*, 1557–1572. [CrossRef]
17. Turnbull, L.; Wainwright, J.; Brazier, R.E. A conceptual framework for understanding semi-arid land degradation: Ecohydrological interactions across multiple-space and time scales. *Ecohydrology* **2008**, *1*, 23–34. [CrossRef]
18. Okin, G.S.; De Las Heras, M.M.; Saco, P.M.; Throop, H.L.; Vivoni, E.R.; Parsons, A.J.; Wainwright, J.; Peters, D.P.C. Connectivity in dryland landscapes: Shifting concepts of spatial interactions. *Front. Ecol. Environ.* **2015**, *13*, 20–27. [CrossRef]

19. Knudby, C.; Carrera, J. On the relationship between indicators of geostatistical, flow and transport connectivity. *Adv. Water Resour.* **2005**, *28*, 405–421. [CrossRef]
20. Lexartza-Artza, I.; Wainwright, J. Hydrological connectivity: Linking concepts with practical implications. *Catena* **2009**, *79*, 146–152. [CrossRef]
21. Baartman, J.E.M.; Nunes, J.P.; Masselink, R.; Darboux, F.; Bielders, C.; Degré, A.; Cantreul, V.; Cerdan, O.; Grangeon, T.; Fiener, P.; et al. What do models tell us about water and sediment connectivity? *Geomorphology* **2020**, *367*, 107300. [CrossRef]
22. Kirkby, M.; Bracken, L.; Reaney, S. The influence of land use, soils and topography on the delivery of hillslope runoff to channels in SE Spain. *Earth Surf. Process. Landf.* **2002**, *27*, 1459–1473. [CrossRef]
23. Garbin, S.; Celegon, E.A.; Fanton, P.; Botter, G. Hydrological controls on river network connectivity. *R. Soc. Open Sci.* **2019**, *6*, 181428. [CrossRef] [PubMed]
24. Stavi, I.; Rachmilevitch, S.; Yizhaq, H. Small-scale Geodiversity Regulates Functioning, Connectivity, and Productivity of Shrubby, Semi-arid Rangelands. *Land Degrad. Dev.* **2018**, *29*, 205–209. [CrossRef]
25. Poeppl, R.E.; Keesstra, S.D.; Maroulis, J. A conceptual connectivity framework for understanding geomorphic change in human-impacted fluvial systems. *Geomorphology* **2017**, *277*, 237–250. [CrossRef]
26. López-Vicente, M.; Nadal-Romero, E.; Cammeraat, E.L.H. Hydrological Connectivity Does Change over 70 Years of Abandonment and Afforestation in the Spanish Pyrenees. *Land Degrad. Dev.* **2017**, *28*, 1298–1310. [CrossRef]
27. Deng, X.; Xu, Y.; Han, L. Impacts of human activities on the structural and functional connectivity of a river network in the Taihu Plain. *Land Degrad. Dev.* **2018**, *29*, 2575–2588. [CrossRef]
28. Lizaga, I.; Quijano, L.; Palazón, L.; Gaspar, L.; Navas, A. Enhancing Connectivity Index to Assess the Effects of Land Use Changes in a Mediterranean Catchment. *Land Degrad. Dev.* **2018**, *29*, 663–675. [CrossRef]
29. Steele, M.K.; Heffernan, J.B. Morphological characteristics of urban water bodies: Mechanisms of change and implications for ecosystem function. *Ecol. Appl.* **2014**, *24*, 1070–1084. [CrossRef]
30. Wohl, E.; Brierley, G.; Cadol, D.; Coulthard, T.J.; Covino, T.; Fryirs, K.A.; Grant, G.; Hilton, R.G.; Lane, S.N.; Magilligan, F.J.; et al. Connectivity as an emergent property of geomorphic systems. *Earth Surf. Process. Landf.* **2019**, *44*, 4–26.
31. Bires, Z.; Raj, S. Determinants of environmental conservation in Lake Tana Biosphere Reserve, Ethiopia. *Heliyon* **2019**, *5*, e01997. [CrossRef] [PubMed]
32. Adugna, G.; Bekele, W. Determinants of Land Degradation in the Lake Tana Basin and Its Implications for Sustainable Land Management: The Case of Angereb and Gish-Abbay Watersheds Determinants of Land Degradation in the Lake Tana Basin and Its Implications for Sustainable Land. *Eth. J. Agric. Econ.* **2007**, *6*, 69–101.
33. Bogale, A.; Aynalem, D.; Adem, A.; Mekuria, W.; Tilahun, S. Spatial and temporal variability of soil loss in gully erosion in upper Blue Nile basin, Ethiopia. *Appl. Water Sci.* **2020**, *10*, 106. [CrossRef]
34. Bogale, A. Review, impact of land use/cover change on soil erosion in the Lake Tana Basin, Upper Blue Nile, Ethiopia. *Appl. Water Sci.* **2020**, *10*, 235. [CrossRef]
35. Weldegebriel, L.; Kruskopf, M.; Thompson, S.E. Detecting the short term impact of soil and water conservation practices using stage as a proxy for discharge—A case-study from the Tana sub-basin, Ethiopia. *Land Degrad. Dev.* **2021**, *32*, 867–880. [CrossRef]
36. Goshu, G.; Aynalem, S. Problem Overview of the Lake Tana Basin. In *Social and Ecological System Dynamics*; Springer: Cham, Switzerland, 2017; pp. 9–23.
37. Alemu, M.L.; Worqlul, A.W.; Zimale, F.A.; Tilahun, S.A.; Steenhuis, T.S. Water balance for a tropical lake in the volcanic highlands: Lake tana, ethiopia. *Water* **2020**, *12*, 2737. [CrossRef]
38. Geremew, A.; Triest, L. Hydrological connectivity and vegetative dispersal shape clonal and genetic structure of the emergent macrophyte Cyperus papyrus in a tropical highland lake (Lake Tana, Ethiopia). *Hydrobiologia* **2019**, *843*, 13–30. [CrossRef]
39. Abdo, K.S.; Fiseha, B.M.; Rientjes, T.H.M.; Gieske, A.S.M.; Haile, A.T. Assessment of climate change impacts on the hydrology of Gilgel Abay catchment in Lake Tana basin, Ethiopia. *Hydrol. Process.* **2009**, *23*, 3661–3669. [CrossRef]
40. Haile, A.T.; Akawka, A.L.; Berhanu, B.; Rientjes, T. Changes in water availability in the Upper Blue Nile basin under the representative concentration pathways scenario. *Hydrol. Sci. J.* **2017**, *62*, 2139–2149. [CrossRef]
41. Asitatikie, A.N.; Gebeyehu, W.Z. Assessment of hydrology and optimal water allocation under changing climate conditions: The case of Megech river sub basin reservoir, Upper Blue Nile Basin, Ethiopia. *Model. Earth Syst. Environ.* **2020**, *7*, 2629–2642. [CrossRef]
42. Habib, E.; Haile, A.T.; Sazib, N.; Zhang, Y.; Rientjes, T. Effect of bias correction of satellite-rainfall estimates on runoff simulations at the source of the Upper Blue Nile. *Remote Sens.* **2014**, *6*, 6688–6708. [CrossRef]
43. Worqlul, A.W.; Yen, H.; Collick, A.S.; Tilahun, S.A.; Langan, S.; Steenhuis, T.S. Evaluation of CFSR, TMPA 3B42 and ground-based rainfall data as input for hydrological models, in data-scarce regions: The upper Blue Nile Basin, Ethiopia. *Catena* **2017**, *152*, 242–251. [CrossRef]
44. Worqlul, A.W.; Ayana, E.K.; Maathuis, B.H.P.; MacAlister, C.; Philpot, W.D.; Osorio Leyton, J.M.; Steenhuis, T.S. Performance of bias corrected MPEG rainfall estimate for rainfall-runoff simulation in the upper Blue Nile Basin, Ethiopia. *J. Hydrol.* **2018**, *556*, 1182–1191. [CrossRef]
45. Dile, Y.T.; Berndtsson, R.; Setegn, S.G. Hydrological Response to Climate Change for Gilgel Abay River, in the Lake Tana Basin—Upper Blue Nile Basin of Ethiopia. *PLoS ONE* **2013**, *8*, 12–17. [CrossRef] [PubMed]

46. Robi, M.A.; Abebe, A.; Pingale, S.M. Flood hazard mapping under a climate change scenario in a Ribb catchment of Blue Nile River basin, Ethiopia. *Appl. Geomat.* **2019**, *11*, 147–160. [CrossRef]
47. Roth, V.; Lemann, T.; Zeleke, G.; Subhatu, A.T.; Nigussie, T.K.; Hurni, H. Effects of climate change on water resources in the upper Blue Nile Basin of Ethiopia. *Heliyon* **2018**, *4*, e00771. [CrossRef]
48. Chakilu, G.G.; Sándor, S.; Zoltán, T. Change in stream flow of gumara watershed, upper blue nile basin, ethiopia under representative concentration pathway climate change scenarios. *Water* **2020**, *12*, 3046. [CrossRef]
49. Setegn, S.G.; Rayner, D.; Melesse, A.M.; Dargahi, B.; Srinivasan, R. Impact of climate change on the hydroclimatology of Lake Tana Basin, Ethiopia. *Water Resour. Res.* **2011**, *47*, 1–13. [CrossRef]
50. Ali, Y.S.A.; Crosato, A.; Mohamed, Y.A.; Abdalla, S.H.; Wright, N.G. Sediment balances in the Blue Nile River Basin. *Int. J. Sediment Res.* **2014**, *29*, 316–328. [CrossRef]
51. Ayana, E.K.; Dile, Y.T.; Narasimhan, B.; Srinivasan, R. Dividends in flow prediction improvement using high-resolution soil database. *J. Hydrol. Reg. Stud.* **2019**, *21*, 159–175. [CrossRef]
52. Ayele, G.T.; Teshale, E.Z.; Yu, B.; Rutherfurd, I.D.; Jeong, J. Streamflow and sediment yield prediction for watershed prioritization in the upper Blue Nile river basin, Ethiopia. *Water* **2017**, *9*, 782. [CrossRef]
53. Dessie, M.; Verhoest, N.E.C.; Pauwels, V.R.N.; Admasu, T.; Poesen, J.; Adgo, E.; Deckers, J.; Nyssen, J. Analyzing runoff processes through conceptual hydrological modeling in the Upper Blue Nile Basin, Ethiopia. *Hydrol. Earth Syst. Sci.* **2014**, *18*, 5149–5167. [CrossRef]
54. Duan, Z.; Tuo, Y.; Liu, J.; Gao, H.; Song, X.; Zhang, Z.; Yang, L.; Mekonnen, D.F. Hydrological evaluation of open-access precipitation and air temperature datasets using SWAT in a poorly gauged basin in Ethiopia. *J. Hydrol.* **2019**, *569*, 612–626. [CrossRef]
55. Tegegne, G.; Park, D.K.; Kim, Y.O. Comparison of hydrological models for the assessment of water resources in a data-scarce region, the Upper Blue Nile River Basin. *J. Hydrol. Reg. Stud.* **2017**, *14*, 49–66. [CrossRef]
56. Tigabu, T.B.; Hörmann, G.; Wagner, P.D.; Fohrer, N. Statistical analysis of rainfall and streamflow time series in the Lake Tana Basin, Ethiopia. *J. Water Clim. Chang.* **2020**, *11*, 258–273. [CrossRef]
57. Wagena, M.B.; Sommerlot, A.; Abiy, A.Z.; Collick, A.S.; Langan, S.; Fuka, D.R.; Easton, Z.M. Climate change in the Blue Nile Basin Ethiopia: Implications for water resources and sediment transport. *Clim. Chang.* **2016**, *139*, 229–243. [CrossRef]
58. Worqlul, A.W.; Ayana, E.K.; Yen, H.; Jeong, J.; MacAlister, C.; Taylor, R.; Gerik, T.J.; Steenhuis, T.S. Evaluating hydrologic responses to soil characteristics using SWAT model in a paired-watersheds in the Upper Blue Nile Basin. *Catena* **2018**, *163*, 332–341. [CrossRef]
59. Setegn, S.G.; Srinivasen, R.; Melesse, A.M.; Dargahi, B. SWAT model application and prediction uncertainty analysis in the Lake Tana Basin, Ethiopia. *Hydrol. Process.* **2010**, *24*, 357–367. [CrossRef]
60. Tegegne, G.; Kim, Y.O. Modelling ungauged catchments using the catchment runoff response similarity. *J. Hydrol.* **2018**, *564*, 452–466. [CrossRef]
61. Moges, M.A.; Schmitter, P.; Tilahun, S.A.; Langan, S.; Dagnew, D.C.; Akale, A.T.; Steenhuis, T.S. Suitability of Watershed Models to Predict Distributed Hydrologic Response in the Awramba Watershed in Lake Tana Basin. *Land Degrad. Dev.* **2017**, *28*, 1386–1397. [CrossRef]
62. Ayele, H.S.; Li, M.H.; Tung, C.P.; Liu, T.M. Impact of climate change on runoff in the Gilgel Abbay watershed, the upper Blue Nile Basin, Ethiopia. *Water* **2016**, *8*, 380. [CrossRef]
63. Taye, M.T.; Ntegeka, V.; Ogiramoi, N.P.; Willems, P. Assessment of climate change impact on hydrological extremes in two source regions of the Nile River Basin. *Hydrol. Earth Syst. Sci.* **2011**, *15*, 209–222. [CrossRef]
64. Tigabu, T.B.; Wagner, P.D.; Hörmann, G.; Fohrer, N. Modeling the spatio-temporal flow dynamics of groundwater-surface water interactions of the Lake Tana Basin, Upper Blue Nile, Ethiopia. *Hydrol. Res.* **2020**, *51*, 1537–1559. [CrossRef]
65. Ayana, E.K.; Worqlul, A.W.; Steenhuis, T.S. Evaluation of stream water quality data generated from MODIS images in modeling total suspended solid emission to a freshwater lake. *Sci. Total Environ.* **2015**, *523*, 170–177. [CrossRef]
66. Woldesenbet, T.A.; Elagib, N.A.; Ribbe, L.; Heinrich, J. Hydrological responses to land use/cover changes in the source region of the Upper Blue Nile Basin, Ethiopia. *Sci. Total Environ.* **2017**, *575*, 724–741. [CrossRef] [PubMed]
67. Berihun, M.L.; Tsunekawa, A.; Haregeweyn, N.; Dile, Y.T.; Tsubo, M.; Fenta, A.A.; Meshesha, D.T.; Ebabu, K.; Sultan, D.; Srinivasan, R. Evaluating runoff and sediment responses to soil and water conservation practices by employing alternative modeling approaches. *Sci. Total Environ.* **2020**, *747*, 141118. [CrossRef] [PubMed]
68. Lemma, H.; Frankl, A.; van Griensven, A.; Poesen, J.; Adgo, E.; Nyssen, J. Identifying erosion hotspots in Lake Tana Basin from a multisite Soil and Water Assessment Tool validation: Opportunity for land managers. *Land Degrad. Dev.* **2019**, *30*, 1449–1467. [CrossRef]
69. Alemu, M.L.; Geset, M.; Mosa, H.M.; Zemale, F.A.; Moges, M.A.; Giri, S.K.; Tillahun, S.A.; Melesse, A.M.; Ayana, E.K.; Steenhuis, T.S. Spatial and Temporal Trends of Recent Dissolved Phosphorus Concentrations in Lake Tana and its Four Main Tributaries. *Land Degrad. Dev.* **2017**, *28*, 1742–1751. [CrossRef]
70. Tigabu, T.B.; Wagner, P.D.; Hörmann, G.; Fohrer, N. Modeling the impact of agricultural crops on the spatial and seasonal variability of water balance components in the Lake Tana basin, Ethiopia. *Hydrol. Res.* **2019**, *50*, 1376–1396. [CrossRef]
71. Teklay, A.; Dile, Y.T.; Setegn, S.G.; Demissie, S.S.; Asfaw, D.H. Evaluation of static and dynamic land use data for watershed hydrologic process simulation: A case study in Gummara watershed, Ethiopia. *Catena* **2019**, *172*, 65–75. [CrossRef]

72. Tikuye, G.B.; Manjunatha, B.R.; Gangadhara Bhat, H. Modeling impacts of projected climate and land use/land cover change on hydrological responses in the Lake Tana Basin, Upper Blue Nile River Basin, Ethiopia. *J. Hydrol.* **2021**, *595*, 125974.
73. Gumindoga, W.; Rientjes, T.H.M.; Tamiru Haile, A.; Makurira, H.; Reggiani, P. Performance of bias-correction schemes for CMORPH rainfall estimates in the Zambezi River basin. *Hydrol. Earth Syst. Sci.* **2019**, *23*, 2915–2938. [CrossRef]
74. Birhanu, A.; Masih, I.; van der Zaag, P.; Nyssen, J.; Cai, X. Impacts of land use and land cover changes on hydrology of the Gumara catchment, Ethiopia. *Phys. Chem. Earth* **2019**, *112*, 165–174. [CrossRef]
75. Woldesenbet, T.A.; Elagib, N.A.; Ribbe, L.; Heinrich, J. Catchment response to climate and land use changes in the Upper Blue Nile sub-basins, Ethiopia. *Sci. Total Environ.* **2018**, *644*, 193–206. [CrossRef]
76. Addisu, S.; Kassawmar, B.; Mekuriaw, A.; Haileslassie, A. Geographic Information System based suitability analysis for potentials and challenges of small-scale irrigation in Lake Tana sub-basin, Ethiopia. *Int. J. River Basin Manag.* **2019**, *19*, 81–92. [CrossRef]
77. Addis, H.K.; Strohmeier, S.; Ziadat, F.; Melaku, N.D.; Klik, A. Modeling streamflow and sediment using SWAT in Ethiopian highlands. *Int. J. Agric. Biol. Eng.* **2016**, *9*, 51–66.
78. Andualem, T.G.; Guadie, A.; Belay, G.; Ahmad, I.; Dar, M.A. Hydrological modeling of Upper Ribb watershed, Abbay basin, Ethiopia. *Glob. Nest J.* **2020**, *22*, 158–164.
79. Melaku, N.D.; Renschler, C.S.; Holzmann, H.; Strohmeier, S.; Bayu, W.; Zucca, C.; Ziadat, F.; Klik, A. Prediction of soil and water conservation structure impacts on runoff and erosion processes using SWAT model in the northern Ethiopian highlands. *J. Soils Sediments* **2018**, *18*, 1743–1755. [CrossRef]
80. Monsieurs, E.; Dessie, M.; Verhoest, N.E.C.; Poesen, J.; Adgo, E.; Deckers, J.; Nyssen, J. Impact of draining hilly lands on runoff and on-site erosion: A case study from humid Ethiopia. *Earth Surf. Process. Landf.* **2016**, *41*, 513–525. [CrossRef]
81. Akale, A.T.; Dagnew, D.C.; Belete, M.A.; Tilahun, S.A.; Mekuria, W.; Steenhuis, T.S. Impact of soil depth and topography on the effectiveness of conservation practices on discharge and soil loss in the Ethiopian highlands. *Land* **2017**, *6*, 78. [CrossRef]
82. Adem, A.A.; Addis, G.G.; Aynalem, D.W.; Tilahun, S.A.; Mekuria, W.; Azeze, M.; Steenhuis, T.S. Hydrogeology of volcanic highlands affects prioritization of land management practices. *Water* **2020**, *12*, 2702. [CrossRef]
83. Abera, A.; Verhoest, N.E.C.; Tilahun, S.; Inyang, H.; Nyssen, J. Assessment of irrigation expansion and implications for water resources by using RS and GIS techniques in the Lake Tana Basin of Ethiopia. *Environ. Monit. Assess.* **2021**, *193*, 13. [CrossRef] [PubMed]
84. Nigate, F.; Camp, M.V.; Yenehun, A.; Belay, A.S.; Walraevens, K. Recharge-discharge relations of groundwater in volcanic terrain of semi-humid tropical highlands of Ethiopia: The case of Infranz springs, in the Upper Blue Nile. *Water* **2020**, *12*, 853. [CrossRef]
85. Lemma, H.; Frankl, A.; Dessie, M.; Poesen, J.; Adgo, E.; Nyssen, J. Consolidated sediment budget of Lake Tana, Ethiopia (2012–2016). *Geomorphology* **2020**, *371*, 107434. [CrossRef]
86. Moges, D.M.; Bhat, H.G. Integration of geospatial technologies with RUSLE for analysis of land use/cover change impact on soil erosion: Case study in Rib watershed, north-western highland Ethiopia. *Environ. Earth Sci.* **2017**, *76*, 765. [CrossRef]
87. Frankl, A.; Nyssen, J.; Adgo, E.; Wassie, A.; Scull, P. Can woody vegetation in valley bottoms protect from gully erosion? Insights using remote sensing data (1938–2016) from subhumid NW Ethiopia. *Reg. Environ. Chang.* **2019**, *19*, 2055–2068.
88. Enku, T.; Tadesse, A.; Yilak, D.L.; Gessesse, A.A.; Addisie, M.B.; Abate, M.; Zimale, F.A.; Moges, M.A.; Tilahun, S.A.; Steenhuis, T.S. Biohydrology of low flows in the humid Ethiopian highlands: The Gilgel Abay catchment. *Biologia* **2014**, *69*, 1502–1509. [CrossRef]
89. Ebabu, K.; Tsunekawa, A.; Haregeweyn, N.; Adgo, E.; Meshesha, D.T.; Aklog, D.; Masunaga, T.; Tsubo, M.; Sultan, D.; Fenta, A.A.; et al. Exploring the variability of soil properties as influenced by land use and management practices: A case study in the Upper Blue Nile basin, Ethiopia. *Soil Tillage Res.* **2020**, *200*, 104614. [CrossRef]
90. Wubie, M.A.; Assen, M. Effects of land cover changes and slope gradient on soil quality in the Gumara watershed, Lake Tana basin of North–West Ethiopia. *Model. Earth Syst. Environ.* **2020**, *6*, 85–97. [CrossRef]
91. Tamene, G.M.; Adiss, H.K.; Alemu, M.Y. Effect of Slope Aspect and Land Use Types on Selected Soil Physicochemical Properties in North Western Ethiopian Highlands. *Appl. Environ. Soil Sci.* **2020**, *2020*, 8463259. [CrossRef]
92. Dile, Y.T.; Tekleab, S.; Kaba, E.A.; Gebrehiwot, S.G.; Worqlul, A.W.; Bayabil, H.K.; Yimam, Y.T.; Tilahun, S.A.; Daggupati, P.; Karlberg, L.; et al. Advances in water resources research in the Upper Blue Nile basin and the way forward: A review. *J. Hydrol.* **2018**, *560*, 407–423. [CrossRef]
93. Uhlenbrook, S.; Roser, S.; Tilch, N. Hydrological process representation at the meso-scale: The potential of a distributed, conceptual catchment model. *J. Hydrol.* **2004**, *291*, 278–296. [CrossRef]
94. Lemma, H.; Admasu, T.; Dessie, M.; Fentie, D.; Deckers, J.; Frankl, A.; Poesen, J.; Adgo, E.; Nyssen, J. Revisiting lake sediment budgets: How the calculation of lake lifetime is strongly data and method dependent. *Earth Surf. Process. Landf.* **2018**, *43*, 593–607. [CrossRef]
95. Dargahi, B.; Setegn, S.G. Combined 3D hydrodynamic and watershed modelling of Lake Tana, Ethiopia. *J. Hydrol.* **2011**, *398*, 44–64. [CrossRef]
96. Lemann, T.; Roth, V.; Zeleke, G.; Subhatu, A.; Kassawmar, T.; Hurni, H. Spatial and temporal variability in hydrological responses of the upper Blue Nile basin, Ethiopia. *Water* **2018**, *11*, 21. [CrossRef]
97. Setegn, S.G.; Srinivasan, R.; Dargahi, B.; Melesse, A.M. Spatial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia. *Hydrol. Process.* **2009**, *23*, 3738–3750. [CrossRef]

98. Polanco, E.I.; Fleifle, A.; Ludwig, R.; Disse, M. Improving SWAT model performance in the Upper Blue Nile River Basin using meteorological data integration and catchment scaling. *Hydrol. Earth Syst. Sci. Discuss.* **2017**, *21*, 4907–4926. [CrossRef]
99. Uhlenbrook, S.; Mohamed, Y.; Gragne, A.S. Analyzing catchment behavior through catchment modeling in the Gilgel Abay, Upper Blue Nile River Basin, Ethiopia. *Hydrol. Earth Syst. Sci.* **2010**, *14*, 2153–2165. [CrossRef]
100. Rientjes, T.H.M.; Haile, A.T.; Kebede, E.; Mannaerts, C.M.M.; Habib, E.; Steenhuis, T.S. Changes in land cover, rainfall and stream flow in Upper Gilgel Abbay catchment, Blue Nile basin—Ethiopia. *Hydrol. Earth Syst. Sci.* **2011**, *15*, 1979–1989. [CrossRef]
101. Wale, A.; Rientjes, T.H.M.; Gieske, A.S.M.; Getachew, H.A. Ungauged catchment contributions to Lake Tana's water balance. *Hydrol. Process.* **2009**, *23*, 3682–3693. [CrossRef]
102. Zimale, F.A.; Moges, M.A.; Alemu, M.L.; Ayana, E.K.; Demissie, S.S.; Tilahun, S.A.; Steenhuis, T.S. Budgeting suspended sediment fluxes in tropical monsoonal watersheds with limited data: The Lake Tana basin. *J. Hydrol. Hydromech.* **2018**, *66*, 65–78. [CrossRef]
103. Moges, M.A.; Schmitter, P.; Tilahun, S.A.; Steenhuis, T.S. Watershed modeling for reducing future non-point source sediment and phosphorus load in the Lake Tana Basin, Ethiopia. *J. Soils Sediments* **2018**, *18*, 309–322. [CrossRef]
104. Khadim, F.K.; Dokou, Z.; Lazin, R.; Moges, S.; Bagtzoglou, A.C.; Anagnostou, E. Groundwater modeling in data scarce aquifers: The case of Gilgel-Abay, Upper Blue Nile, Ethiopia. *J. Hydrol.* **2020**, *590*, 125214. [CrossRef]
105. Chebud, Y.A.; Melesse, A.M. Numerical modeling of the groundwater flow system of the Gumera sub-basin in Lake Tana basin, Ethiopia. *Hydrol. Process.* **2009**, *23*, 3694–3704. [CrossRef]
106. Alemayehu, T.; McCartney, M.; Kebede, S. The water resource implications of planned development in the lake Tana catchment, Ethiopia. *Ecohydrol. Hydrobiol.* **2010**, *10*, 211–221. [CrossRef]
107. Haile, A.T.; Rientjes, T.; Gieske, A.; Gebremichael, M. Rainfall variability over mountainous and adjacent lake areas: The case of Lake Tana basin at the source of the Blue Nile River. *J. Appl. Meteorol. Climatol.* **2009**, *48*, 1696–1717. [CrossRef]
108. Duan, Z.; Bastiaanssen, W.G.M. First results from Version 7 TRMM 3B43 precipitation product in combination with a new downscaling-calibration procedure. *Remote Sens. Environ.* **2013**, *131*, 1–13. [CrossRef]
109. Haile, A.T.; Yan, F.; Habib, E. Accuracy of the CMORPH satellite-rainfall product over Lake Tana Basin in Eastern Africa. *Atmos. Res.* **2015**, *163*, 177–187. [CrossRef]
110. Fetene, Z.A.; Weldegerima, T.M.; Zeleke, T.T.; Nigussie, M. Harmonic Analysis of Precipitation Time Series in Lake Tana Basin, Ethiopia. *Adv. Meteorol.* **2018**, *2018*, 1598195. [CrossRef]
111. Weldegerima, T.M.; Zeleke, T.T.; Birhanu, B.S.; Zaitchik, B.F.; Fetene, Z.A. Analysis of Rainfall Trends and Its Relationship with SST Signals in the Lake Tana Basin, Ethiopia. *Adv. Meteorol.* **2018**, *2018*, 5869010. [CrossRef]
112. Samy, A.; Ibrahim, M.G.; Mahmod, W.E.; Fujii, M.; Eltawil, A.; Daoud, W. Statistical assessment of rainfall characteristics in upper Blue Nile basin over the period from 1953 to 2014. *Water* **2019**, *11*, 468. [CrossRef]
113. Abebe, S.A.; Qin, T.; Yan, D.; Gelaw, E.B.; Workneh, H.T.; Kun, W.; Shanshan, L.; Biqiong, D. Spatial and temporal evaluation of the latest high-resolution precipitation products over the Upper Blue Nile river basin, Ethiopia. *Water* **2020**, *12*, 3072. [CrossRef]
114. Ayehu, G.T.; Tadesse, T.; Gessesse, B.; Dinku, T. Validation of new satellite rainfall products over the Upper Blue Nile Basin, Ethiopia. *Atmos. Meas. Tech.* **2018**, *11*, 1921–1936. [CrossRef]
115. Alemu, M.M.; Bawoke, G.T. Analysis of spatial variability and temporal trends of rainfall in Amhara Region, Ethiopia. *J. Water Clim. Chang.* **2020**, *11*, 1505–1520. [CrossRef]
116. Alemseged, T.H.; Tom, R. Evaluation of regional climate model simulations of rainfall over the Upper Blue Nile basin. *Atmos. Res.* **2015**, *161–162*, 57–64. [CrossRef]
117. Belete, M.; Deng, J.; Wang, K.; Zhou, M.; Zhu, E.; Shifaw, E.; Bayissa, Y. Evaluation of satellite rainfall products for modeling water yield over the source region of Blue Nile Basin. *Sci. Total Environ.* **2020**, *708*, 134834. [CrossRef]
118. Bhatti, H.A.; Rientjes, T.; Haile, A.T.; Habib, E.; Verhoef, W. Evaluation of bias correction method for satellite-based rainfall data. *Sensors* **2016**, *16*, 884. [CrossRef]
119. Fenta, A.A.; Yasuda, H.; Shimizu, K.; Ibaraki, Y.; Haregeweyn, N.; Kawai, T.; Belay, A.S.; Sultan, D.; Ebabu, K. Evaluation of satellite rainfall estimates over the Lake Tana basin at the source region of the Blue Nile River. *Atmos. Res.* **2018**, *212*, 43–53. [CrossRef]
120. Worqlul, A.W.; Maathuis, B.; Adem, A.A.; Demissie, S.S.; Langan, S.; Steenhuis, T.S. Comparison of rainfall estimations by TRMM 3B42, MPEG and CFSR with ground-observed data for the Lake Tana basin in Ethiopia. *Hydrol. Earth Syst. Sci.* **2014**, *18*, 4871–4881. [CrossRef]
121. Addisu, S.; Selassie, Y.G.; Fissha, G.; Gedif, B. Time series trend analysis of temperature and rainfall in lake Tana Sub-basin, Ethiopia. *Environ. Syst. Res.* **2015**, *4*, 25. [CrossRef]
122. Rientjes, T.; Haile, A.T.; Fenta, A.A. Diurnal rainfall variability over the Upper Blue Nile Basin: A remote sensing based approach. *Int. J. Appl. Earth Obs. Geoinf.* **2012**, *21*, 311–325. [CrossRef]
123. Sisay, E.; Halefom, A.; Teshome, A. Impacts of land use/land cover detection on climate variability of Gumara Watershed, Ethiopia. *Int. J. Water* **2019**, *13*, 101–121. [CrossRef]
124. Minale, A.S.; Kameswara Rao, K. Impacts of land cover/use dynamics of Gilgel Abbay catchment of Lake Tana on climate variability, Northwestern Ethiopia. *Appl. Geomat.* **2012**, *4*, 155–162. [CrossRef]
125. Teklay, A.; Dile, Y.T.; Asfaw, D.H.; Bayabil, H.K.; Sisay, K. Impacts of land surface model and land use data on WRF model simulation of rainfall and temperature over the Lake Tana Basin, Ethiopia. *Heliyon* **2019**, *5*, e02469. [CrossRef] [PubMed]

126. Tesemma, Z.K.; Mohamed, Y.A.; Steenhuis, T.S. Trends in rainfall and runoff in the Blue Nile Basin: 1964-2003. *Hydrol. Process.* **2010**, *24*, 3747–3758. [CrossRef]
127. Tekleab, S.; Mohamed, Y.; Uhlenbrook, S. Hydro-climatic trends in the Abay/Upper Blue Nile basin, Ethiopia. *Phys. Chem. Earth* **2013**, *61–62*, 32–42. [CrossRef]
128. Monsieurs, E.; Poesen, J.; Dessie, M.; Adgo, E.; Verhoest, N.E.C.; Deckers, J.; Nyssen, J. Effects of drainage ditches and stone bunds on topographical thresholds for gully head development in North Ethiopia. *Geomorphology* **2015**, *234*, 193–203. [CrossRef]
129. Minale, A.S. Water level fluctuations of Lake Tana and its implication on local communities livelihood, northwestern Ethiopia. *Int. J. River Basin Manag.* **2020**, *18*, 503–510. [CrossRef]
130. Asitatikie, A.N.; Nigussie, E.D. Modeling on naturalization of inflow and outflow nutrients sources of Blue Nile River at the Lake Tana in Basaltic Plateau of Ethiopia. *Model. Earth Syst. Environ.* **2020**, *7*, 2283–2295. [CrossRef]
131. Duan, Z.; Bastiaanssen, W.G.M. Estimating water volume variations in lakes and reservoirs from four operational satellite altimetry databases and satellite imagery data. *Remote Sens. Environ.* **2013**, *134*, 403–416. [CrossRef]
132. Kebedew, M.G.; Tilahun, S.A.; Zimale, F.A.; Steenhuis, T.S. Bottom sediment characteristics of a tropical lake: Lake Tana, Ethiopia. *Hydrology* **2020**, *7*, 18. [CrossRef]
133. Kebedew, M.G.; Kibret, A.A.; Tilahun, S.A.; Belete, M.A.; Zimale, F.A.; Steenhuis, T.S. The relationship of lake morphometry and phosphorus dynamics of a tropical Highland Lake: Lake Tana, Ethiopia. *Water* **2020**, *12*, 2243. [CrossRef]
134. Mucheye, T.; Yitaferu, B.; Zenebe, A. Significance of wetlands for sediment and nutrient reduction in Lake Tana Sub-Basin, Upper Blue Nile Basin, Ethiopia. *Sustain. Water Resour. Manag.* **2018**, *4*, 567–572. [CrossRef]
135. Tsige, A.; Sebhat, M.Y. Rainfall, runoff and soil loss, relationship on different land uses in the upper Lake Tana Basin. *J. Agric. Environ. Int. Dev.* **2018**, *112*, 5–23.
136. Lemma, H.; Nyssen, J.; Frankl, A.; Poesen, J.; Adgo, E.; Billi, P. Bedload transport measurements in the Gilgel Abay River, Lake Tana Basin, Ethiopia. *J. Hydrol.* **2019**, *577*, 123968. [CrossRef]
137. Tekleab, S.; Uhlenbrook, S.; Mohamed, Y.; Savenije, H.H.G.; Temesgen, M.; Wenninger, J. Water balance modeling of Upper Blue Nile catchments using a top-down approach. *Hydrol. Earth Syst. Sci.* **2011**, *15*, 2179–2193. [CrossRef]
138. Kebede, S.; Travi, Y.; Alemayehu, T.; Marc, V. Water balance of Lake Tana and its sensitivity to fluctuations in rainfall, Blue Nile basin, Ethiopia. *J. Hydrol.* **2006**, *316*, 233–247. [CrossRef]
139. Abate, M.; Nyssen, J.; Steenhuis, T.S.; Moges, M.M.; Tilahun, S.A.; Enku, T.; Adgo, E. Morphological changes of Gumara River channel over 50 years, upper Blue Nile basin, Ethiopia. *J. Hydrol.* **2015**, *525*, 152–164. [CrossRef]
140. Abate, M.; Nyssen, J.; Moges, M.M.; Enku, T.; Zimale, F.A.; Tilahun, S.A.; Adgo, E.; Steenhuis, T.S. Long-Term Landscape Changes in the Lake Tana Basin as Evidenced by Delta Development and Floodplain Aggradation in Ethiopia. *Land Degrad. Dev.* **2017**, *28*, 1820–1830. [CrossRef]
141. Mulatu, C.A.; Crosato, A.; Moges, M.M.; Langendoen, E.J.; McClain, M. Morphodynamic trends of the Ribb River, Ethiopia, prior to dam construction. *Geosciences* **2018**, *8*, 255. [CrossRef]
142. Poppe, L.; Frankl, A.; Poesen, J.; Admasu, T.; Dessie, M.; Adgo, E.; Deckers, J.; Nyssen, J. Geomorphology of the Lake Tana basin, Ethiopia. *J. Maps* **2013**, *9*, 431–437. [CrossRef]
143. Song, C.; Nigatu, L.; Beneye, Y.; Abdulahi, A.; Zhang, L.; Wu, D. Mapping the vegetation of the Lake Tana basin, Ethiopia, using Google Earth images. *Earth Syst. Sci. Data* **2018**, *10*, 2033–2041. [CrossRef]
144. Abiye, T.A.; Kebede, S. The role of geodiversity on the groundwater resource potential in the upper Blue Nile River Basin, Ethiopia. *Environ. Earth Sci.* **2011**, *64*, 1283–1291. [CrossRef]
145. Berhanu, K.G.; Hatiye, S.D. Identification of Groundwater Potential Zones Using Proxy Data: Case study of Megech Watershed, Ethiopia. *J. Hydrol. Reg. Stud.* **2020**, *28*, 100676. [CrossRef]
146. Tewabe, D.; Fentahun, T. Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. *Cogent Environ. Sci.* **2020**, *6*, 1778998. [CrossRef]
147. Annys, S.; Van Passel, S.; Dessein, J.; Adgo, E.; Nyssen, J. From fast-track implementation to livelihood deterioration: The dam-based Ribb Irrigation and Drainage Project in Northwest Ethiopia. *Agric. Syst.* **2020**, *184*, 102909. [CrossRef]
148. Worqlul, A.W.; Collick, A.S.; Rossiter, D.G.; Langan, S.; Steenhuis, T.S. Assessment of surface water irrigation potential in the Ethiopian highlands: The Lake Tana Basin. *Catena* **2015**, *129*, 76–85. [CrossRef]
149. Moges, D.M.; Bhat, H.G. An insight into land use and land cover changes and their impacts in Rib watershed, north-western highland Ethiopia. *Land Degrad. Dev.* **2018**, *29*, 3317–3330. [CrossRef]
150. Gessesse, G.D.; Mansberger, R.; Klik, A. Assessment of Rill Erosion Development during Erosive Storm at Angereb Watershed, Lake Tana Sub-basin in Ethiopia. *J. Mt. Sci.* **2015**, *12*, 49–59. [CrossRef]
151. Duan, Z.; Gao, H.; Ke, C. Estimation of lake outflow from the poorly gauged Lake Tana (Ethiopia) using satellite remote sensing data. *Remote Sens.* **2018**, *10*, 1060. [CrossRef]
152. Chebud, Y.A.; Melesse, A.M. Modelling lake stage and water balance of Lake Tana, Ethiopia. *Hydrol. Process.* **2009**, *23*, 3534–3544. [CrossRef]
153. Jothimani, M.; Dawit, Z.; Mulualem, W. Flood Susceptibility Modeling of Megech River Catchment, Lake Tana Basin, North Western Ethiopia, Using Morphometric Analysis. *Earth Syst. Environ.* **2020**, *5*, 353–364. [CrossRef]
154. Conway, D. The Climate and Hydrology of the Upper Blue Nile River. *Geogr. J.* **2020**, *166*, 49–62. [CrossRef]

155. Ahmad, I.; Dar, M.A.; Andualem, T.G. Assessment of soil loss rate—Lake Tana basin, Ethiopia. *Arab. J. Geosci.* **2020**, *13*, 15. [CrossRef]
156. Mhiret, D.A.; Dagnew, D.C.; Assefa, T.T.; Tilahun, S.A.; Zaitchik, B.F.; Steenhuis, T.S. Erosion hotspot identification in the sub-humid Ethiopian highlands. *Ecohydrol. Hydrobiol.* **2019**, *19*, 146–154. [CrossRef]
157. Gashaw, T.; Worqlul, A.W.; Dile, Y.T.; Addisu, S.; Bantider, A.; Zeleke, G. Evaluating potential impacts of land management practices on soil erosion in the Gilgel Abay watershed, upper Blue Nile basin. *Heliyon* **2020**, *6*, e04777. [CrossRef]
158. Surfleet, C.G.; Tullos, D.; Chang, H.; Jung, I.W. Selection of hydrologic modeling approaches for climate change assessment: A comparison of model scale and structures. *J. Hydrol.* **2012**, *464–465*, 233–248. [CrossRef]
159. Nunes, J.P.; Wainwright, J.; Bielders, C.L.; Darboux, F.; Fiener, P.; Finger, D.; Turnbull, L. Better models are more effectively connected models. *Earth Surf. Process. Landf.* **2018**, *43*, 1355–1360.
160. Cavalli, M.; Trevisani, S.; Comiti, F.; Marchi, L. Geomorphometric assessment of spatial sediment connectivity in small Alpine catchments. *Geomorphology* **2013**, *188*, 31–41. [CrossRef]
161. Mishra, K.; Sinha, R.; Jain, V.; Nepal, S.; Uddin, K. Towards the assessment of sediment connectivity in a large Himalayan river basin. *Sci. Total Environ.* **2019**, *661*, 251–265. [CrossRef]
162. Lane, S.N.; Reaney, S.M.; Heathwaite, A.L. Representation of landscape hydrological connectivity using a topographically driven surface flow index. *Water Resour. Res.* **2009**, *45*, W08423. [CrossRef]
163. Walker, D.; Parkin, G.; Gowing, J.; Haile, A.T. Development of a hydrogeological conceptual model for shallow aquifers in the data scarce upper Blue Nile basin. *Hydrology* **2019**, *6*, 43. [CrossRef]
164. Kabanza, A.K.; Dondeyne, S.; Kimaro, D.N.; Kafiriti, E.; Poesen, J.; Deckers, J.A. Effectiveness of soil conservation measures in two contrasting landscape units of South Eastern Tanzania. *Z. Geomorphol.* **2013**, *57*, 269–288. [CrossRef] [PubMed]
165. Achten, W.M.J.D.; Mugogo, S.; Kafiriti, E.; Poesen, J.; Deckers, J.; Muys, B. Gully erosion in South Eastern Tanzania: Spatial distribution and topographic thresholds. *Z. Geomorphol.* **2008**, *52*, 225–235. [CrossRef]