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Riparian Vegetation Quality Assessment Using QBRy Index Across Three Sub-Basins in Kiliti Watershed, Ethiopia

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ABSTRACT

Riparian zones act as vital ecological corridors linking terrestrial and aquatic systems, yet they are increasingly disturbed in tropical watersheds. This study assessed riparian vegetation condition using a locally modified QBRy (Qualitat del Bosc de Ribera) index across thirty sampling sites within the Amen, Kiliti, and Gurdala sub-basins of the Kiliti watershed in Ethiopia. Each site was evaluated for vegetation cover, species composition, structural diversity, and channel modification to determine riparian health status. Comparative statistical analyses revealed significant variation among sub-basins: Gurdala attained the highest mean QBRy score (≈79.5 ± 10.3), followed by Amen (≈60.6 ± 10.0) and Kiliti (≈49.5 ± 6.9). Gurdala sites largely fell within the "Excellent" or "Good" categories, whereas Kiliti was dominated by "Moderate" and "Poor" conditions. A strong positive relationship ($r = 0.76$, $p < 0.01$) between altitude and QBRy indicated that higher elevations tend to support healthier riparian zones, likely due to lower human interference. Vegetation cover and channel condition were the primary factors influencing riparian quality. The QBRy index proved effective as a rapid, integrated approach for evaluating riparian ecosystem health in tropical highland settings.

INTRODUCTION

Riparian forests occupy the boundary between land and water ecosystems and are crucial for maintaining watershed functionality. They contribute significantly to ecosystem regulation by controlling streamflow, filtering sediments and nutrients, reinforcing riverbanks, and sustaining biodiversity and ecological connectivity (Naiman & Decamps, 1997). The state of these forests strongly influences freshwater ecosystem health (Munne et al., 2003).

Despite their importance, riparian areas are increasingly degraded due to human activities such as farming, deforestation, livestock grazing, and urban development, which collectively erode habitat integrity and ecological resilience (Lemma & Desta, 2016; Wassie, 2020). Evaluating riparian forest condition has therefore become essential for effective watershed management and conservation planning (Witing et al., 2022).

Numerous tools both qualitative and quantitative have been developed worldwide to measure riparian ecosystem condition. Among them, the Riparian Forest Quality Index (QBR), first established for Mediterranean rivers, is widely applied for its simplicity and ability to integrate vegetation structure, composition, and human influence into a single measure (Munne et al., 2003). The QBR framework evaluates four main dimensions: vegetation cover, structural complexity,

naturalness, and disturbance level. It has been successfully adjusted for varied regional contexts, from Europe to Asia and Latin America (Magdaleno & Martínez, 2014; Colwell & Hix, 2008).

In Africa, however, few studies have attempted to calibrate the QBR index for local ecological conditions, particularly in tropical highland watersheds. For example, a modified QBR version applied in Sabah, Malaysia, demonstrated that such adaptation is feasible in tropical environments (Chik & Godoong, 2025). In Ethiopia, riparian zones face intense anthropogenic pressures from unregulated land use, and standardized tools to evaluate their ecological quality are scarce (Alemu et al., 2017; Temesgen et al., 2018). Prior Ethiopian studies have mostly emphasized vegetation diversity and composition, with limited focus on integrated quality indices that incorporate both ecological and disturbance parameters (Lemessa & Teka, 2017; Meragiaw et al., 2018; Alemu et al., 2023).

This research addresses that gap by developing and applying a localized version of the QBR termed the QBRy index to assess riparian vegetation quality across the Kiliti watershed in northwestern Ethiopia. The goal is to create a standardized yet adaptable framework that reflects local vegetation types, land-use dynamics, and disturbance patterns. The main contribution of this work lies in contextualizing the established QBR system to Ethiopian highland environments, providing both a diagnostic tool for riparian health and a foundation for future ecological monitoring and restoration strategies.

METHODS

Study area

The study was conducted in the Kiliti (Kiltie) Watershed, located in Dangila District of Awi Zone, Amhara National Regional State, northwestern Ethiopia, within the Upper Blue Nile Basin. The watershed extends approximately from 11°18′30″ to 11°21′30″ N and 36°47′00″ to 36°53′00″ E, covers about 17.74 km², and ranges from approximately 2,023 to 2,208 m above sea level (Denekewu et al., 2026a).

The watershed has a humid subtropical climate with a unimodal rainfall regime, with rainfall concentrated mainly in July and August. Based on 2014–2023 records from the Dangila meteorological station, mean annual rainfall was 1,701.72 mm, while mean annual minimum and maximum temperatures were 10.42 and 25.65 °C, respectively (Denekewu et al., 2026a). The dominant soil is Eutric Nitisol, with sandy-clay to clay textures (Denekewu et al., 2026a).

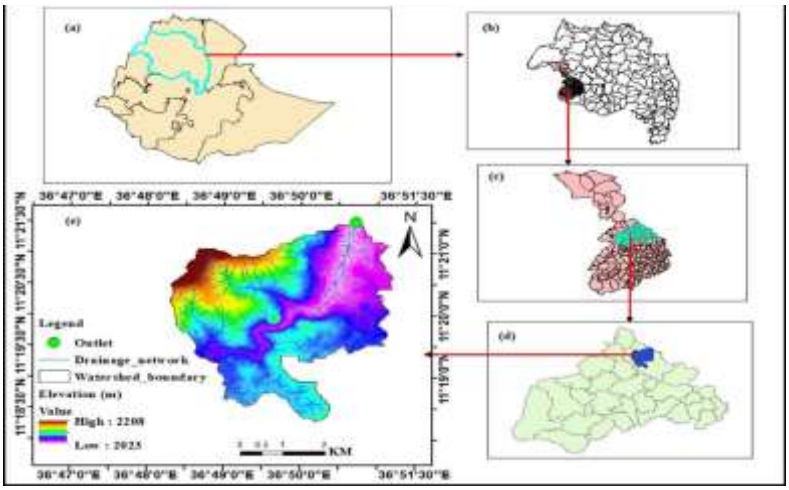


Figure 1. Location and topographic characteristics of the Kiliti Watershed, northwestern Ethiopia. (a) Amhara Region within Ethiopia; (b) Awi Zone within the Amhara Region; (c) Dangila Woreda within Awi Zone; (d) Kiliti Watershed within Dangila Woreda; and (e) detailed topographic map of the Kiliti Watershed showing the watershed boundary, drainage network, outlet, and elevation gradient. Map adapted from. Source: Teshager & Abeje (2021)

Study design

The study was conducted across three sub-basins Amen, Kiliti, and Gurdala representing distinct altitudinal and land-use gradients in Kiliti watershed. A total of thirty riparian sites (ten per sub-basin) were selected to represent upper, middle, and lower stream reaches. Site selection was stratified to capture spatial variation in geomorphology and human disturbance. At each site, field measurements were taken along approximately 100-m river segments following the standard QBR (Qualitat del Bosc de Ribera) framework, adapted as QBRy for local conditions.

Equipment

Data collection employed a handheld GPS (Garmin eTrex 30x) for geographic coordinates and altitude measurements, a laser rangefinder (Nikon Forestry Pro II) for measuring bankfull width and height, and a measuring tape and staff gauge for channel morphology. Field data sheets and photographic documentation were used to record vegetation structure, species composition, and channel alterations.

A Methods Model

The QBRy index was used to assess riparian quality. It consists of four independent components:
Vegetation cover: proportion of riverbanks covered by vegetation within the sampling segment;
Cover quality: relative abundance of native woody species versus exotic or ruderal species;
Vegetation structure: number and diversity of vertical layers (herb, shrub, tree);
Channel alterations: degree of physical modification such as embankments, channelization, or flow regulation.
Each component was scored from 0 to 25 following Munne et al. (1998), and their sum provided the total QBRy score (0–100). Scores were then categorized into four riparian quality classes: Poor (0–25), Moderate (26–50), Good (51–75), and Excellent (76–100).

Data Collection

At each site, vegetation characteristics were recorded using the quadrat observation approach along both riverbanks. Species identification followed regional floristic manuals. For each sub-basin, field data were collected during the dry season to minimize hydrological bias. Environmental attributes such as altitude, latitude, longitude, and mean bankfull height were recorded simultaneously to enable correlation analyses with QBRy values.

2.6. Data analysis

Data were compiled in Microsoft Excel and analyzed using Python (NumPy, pandas, SciPy) and R software (v.4.3.2) (Hayes & Alliance, 2016). Descriptive statistics (mean, median, standard deviation) were computed for QBRy and its components by sub-basin. QBRy values were grouped into quality classes to assess the proportion of sites in each class per sub-basin.

Statistical analysis

Normality of QBRy values was verified using the Shapiro–Wilk test (Chik & Godoong, 2025). Differences in QBRy among sub-basins were examined using one-way analysis of variance (ANOVA). Pearson's correlation coefficient (r) was used to test the relationship between altitude and QBRy. A p-value < 0.05 was considered statistically significant. All tests assumed independent sampling among sites.

RESULTS AND DISCUSSION

Riparian Quality Classes among Sub-Basins

The percentage distribution of riparian quality classes revealed distinct differences among the three sub-basins (Figure 2). Gurdala recorded the highest proportion of Excellent and Good sites, accounting for more than two-thirds of its total. Amen was dominated by Good sites, while Kiliti contained mostly Moderate and Poor categories. Overall, Gurdala displayed the most intact riparian condition, whereas Kiliti showed the strongest signs of degradation.

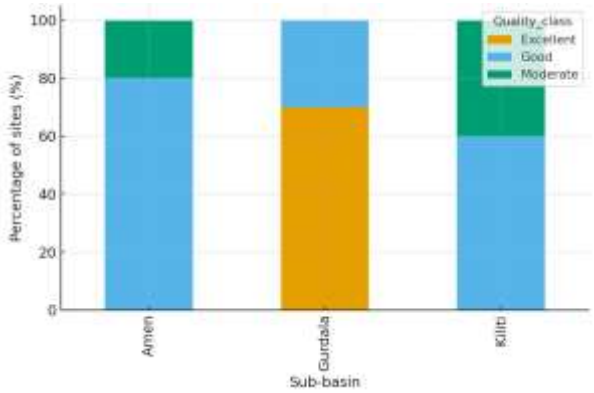


Figure 2. Relative Number of Sites (%) of Each Riparian Quality Class for Each Sub-Basin

Variation of QBRy among sub-basins

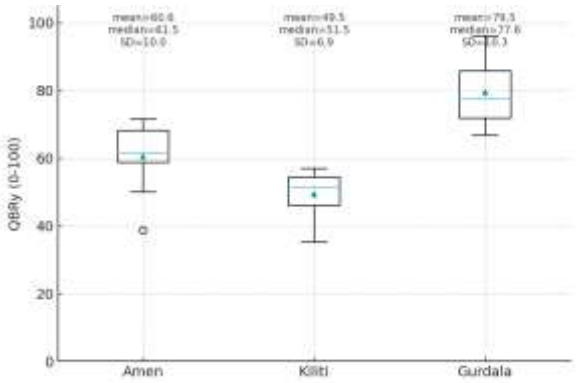


Figure 3. Box-plot of QBRy values (per site) for the three sub-basins

Box-plot analysis showed that mean QBRy scores differed significantly between sub-basins ($p < 0.05$; Figure 3). Gurdala exhibited the highest mean ($\approx 79.5 \pm 10.3$ SD), followed by Amen ($\approx 60.6 \pm 10.0$ SD) and Kiliti ($\approx 49.5 \pm 6.9$ SD). The wider interquartile range in Gurdala suggests higher heterogeneity among its sites, while Kiliti's narrower range reflects consistently lower riparian quality. These results demonstrate a clear spatial gradient of ecological condition across the watershed.

Component Analysis of Qbry Sections

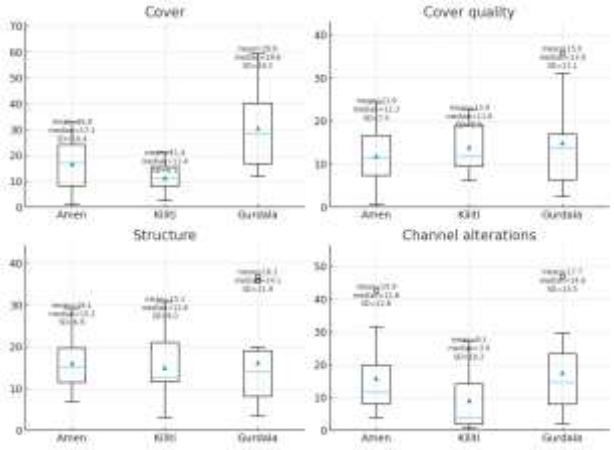


Figure 4. Box-plot of each QBRy section (Cover, Cover quality, Structure, Channel alterations) by sub-basin

The section-wise QBRy assessment (Figure 4) showed that vegetation cover and cover quality contributed most to total QBRy variation. Gurdala scored consistently higher in both, indicating dense, native riparian vegetation. Kiliti exhibited low cover and poor species composition, whereas Amen displayed moderate values across components. Structural diversity was comparable among basins, while channel alterations varied more strongly, with Kiliti showing the highest degree of physical modification.

Relationship between altitude and QBRy

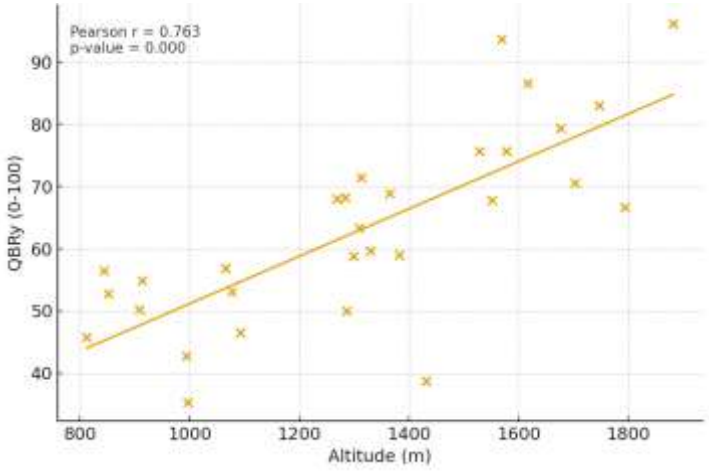


Figure 5. Relationship between altitude and QBRy (correlation + significance)

A strong positive correlation was observed between altitude and total QBRy ($r = 0.76$, $p < 0.01$; Figure 5). Sites at higher elevations generally exhibited better riparian condition. This relationship indicates that human disturbance likely declines with increasing altitude, leading to improved vegetation cover and less channel modification in upper reaches.

Summary of key statistics: Across all sites, QBRy values ranged from 35 to 96, with a mean of approximately 63 ± 15. Standard deviations were lowest in Kiliti, reflecting uniformly reduced riparian condition, and highest in Gurdala, indicating localized variation between highly pristine and moderately impacted reaches.

Discussion

Riparian condition, as represented by the QBR (Qualitat del Bosc de Ribera) index, reflects how land use, vegetation, and geomorphological alterations interact along streams. The QBR framework evaluates four key components vegetation cover, cover quality, structural complexity, and channel alterations and its total score (QBRy in this adaptation) provides an overall measure of ecological integrity (Munne et al., 1998; Martínez et al., 2018). The synthetic results show strong variation among the three studied sub-basins, suggesting differing levels of human influence and ecological resilience.

Gurdala displayed the highest total QBRy values and a larger share of sites in the Excellent and Good classes, whereas Kiliti showed lower scores dominated by Moderate and Poor categories. Amen occupied an intermediate position. These contrasts align with previous findings that riparian quality typically decreases where catchments are subject to intensive cultivation or settlement (Tabacchi et al., 2000; Allan, 2004). High QBRy in Gurdala likely reflects reduced anthropogenic disturbance and a more intact vegetation corridor, while Kiliti's lower values may result from bank modification or vegetation removal.

Breaking down the index into its component sections clarifies which factors drive total scores. Cover and cover quality were particularly low in Kiliti, indicating that vegetation composition and density are the most affected attributes there. Such declines are commonly linked to grazing pressure,

deforestation, or reduced floodplain connectivity (Naiman et al., 2005). Channel alteration scores varied more widely but tended to be higher (better) in Amen and Gurdala, suggesting less morphological modification. Similar patterns have been noted in Mediterranean and tropical basins where channel regulation strongly degrades riparian structure (Aguiar et al., 2011; Kounda et al., 2020).

A significant positive correlation between altitude and QBRy ($r \approx 0.76$, $p < 0.01$) suggests that higher-elevation sites tend to retain better riparian quality. This relationship has been reported elsewhere, as accessibility and land-use pressure typically decline with elevation (Kibret et al., 2019; Benjumea et al., 2021). Still, altitude itself may not be the direct driver but a proxy for disturbance intensity, hydrological regime, and vegetation potential. Interpreting this correlation therefore requires caution and context-specific validation.

Overall, the pattern observed here supports a broader ecological principle: riparian condition mirrors the balance between natural geomorphic processes and anthropogenic alteration (Palmer et al., 2010). The QBRy framework remains a practical, integrative tool for diagnosing this balance and prioritizing management interventions.

CONCLUSION

Riparian quality varied clearly among the three sub-basins, with Gurdala showing the best condition, Amen moderate, and Kiliti the most degraded. Vegetation cover and quality were the main components explaining this variation. The positive link between altitude and QBRy indicates that human pressure likely decreases with elevation. These findings highlight that maintaining native riparian vegetation and minimizing channel alteration are key to sustaining ecological integrity. The QBRy index thus provides an effective means to identify priority areas for conservation and restoration within heterogeneous landscapes

Recomendations

Prioritize riparian restoration in Kiliti: The consistently low QBRy scores and weak vegetation cover point to urgent restoration needs. Replanting native riparian trees and shrubs, fencing stream margins from livestock, and curbing vegetation clearing should be immediate management priorities.

Maintain and monitor high-quality reaches in Gurdala: Gurdala's strong riparian condition makes it a valuable reference sub-basin. Management should focus on preserving its intact vegetation corridors, restricting new agricultural expansion near streambanks, and implementing long-term ecological monitoring to detect emerging pressures early.

Implement targeted management in Amen: Amen's intermediate scores suggest potential recovery with modest interventions. Community-based planting programs and local awareness campaigns on riparian buffer importance could prevent further decline and enhance ecological continuity between reaches.

Integrate riparian buffers into land-use planning: Across all basins, streamside buffer zones of adequate width ($\geq$30 m where possible) should be legally protected or restored. Such buffers reduce sediment and nutrient inflow, stabilize banks, and maintain habitat connectivity (Allan, 2004; Naiman et al., 2005).

Adopt regular QBRy-based monitoring: Institutionalizing periodic QBRy assessments will allow early detection of degradation trends and measure restoration success. Combining QBRy data with land-use and hydrological information can strengthen basin-scale management decisions.

Promote community participation and policy support: Effective riparian conservation depends on local engagement. Training programs for farmers and local administrators, along with incentives for maintaining riparian vegetation, will improve long-term sustainability.

In sum, safeguarding and restoring riparian vegetation particularly in the Kiliti sub-basin will enhance water quality, biodiversity, and resilience of the broader watershed system. The QBRy approach offers a straightforward and scientifically sound foundation for guiding these actions.

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