*Research article*

# Physical Structure Assessment of Rivers Used by Grazing Livestock

**YURI YAMAZAKI***
*Faculty of Agriculture, Tottori University, Tottori, Japan*
*Email: y.yaamazaki@tottori-u.ac.jp*

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**Abstract** In recent years, the demand for meat has increased due to changing dietary habits as well as global population growth. In response to the increased demand for livestock products, grassland ecosystems are increasingly used for grazing and feed crop production, raising concerns about the negative environmental impacts caused by the expansion of livestock production. The author has studied a beef cattle farm that is one of the few farms in Japan that uses forest grazing. There have been concerns about the negative impact of farming grazing livestock near water bodies. When considering sustainable grazing livestock farming, the challenge is to conserve water quality and propose appropriate habitat design to conserve biodiversity. River ecosystem studies require an assessment of the physical environment and surveys of the number of organisms. RHS-HQA is a method developed in the UK and is a relatively easy survey method for obtaining information. This study investigated how grazing cattle use the rivers present in their pastures. A physical environment survey using the RHS-HQA was also carried out to investigate the status of the river on the grazing land. Based on these results, the environmental design of pastureland for sustainable grazing livestock production was discussed, with particular attention to rivers and other riparian areas. The results of the RHS-HQA showed that the river flowing through the target farm was maintained in its natural state, with diverse flow and bed material and a suitable bank environment for biological habitat. Also, the results suggest that by maintaining riparian forest between the grazing land and the river, riverbanks are less likely to become bare or collapse even when grazing cattle use rivers.

**Keywords** physical structure assessment, RHS-HQA, forest-grazing, pasture-based livestock

## INTRODUCTION

There is no question that one of the international challenges we face today is the food problem. Developing countries, the main areas of population growth, have reported a change in diet, shifting from a grain-based diet to a growing demand for meat. The FAO has projected meat consumption to 2050 based on trends in meat consumption from 1961 to 2013; meat consumption is projected to increase rapidly from 376 million tons in 2013 to 557 million tons in 2050.

Jiaguo et al. (2017) investigated the sustainability of current land use and management practices in the Asian Dry Belt, where grassland ecosystems are increasingly used for grazing and forage crop production to meet the increasing demand for livestock products. As a result of their survey, they reported that "While current approaches alleviate the urgent need for short-term livestock production, they need to long-term vulnerability in food security. Trade-offs between short gains and long-term losses, between food for humans and animals, and between agricultural intensification and environmental degradation need to be holistically examined for the region's sustainable development". The relationships between different ecosystem services are very complex; improving the function of one ecosystem service may have "synergies" that enhance the function of other ecosystem services but may also cause "trade-offs" that reduce the function of other ecosystem services.

The author has studied a beef cattle farm that uses forest grazing as one of the few examples in Japan. A small waterway and part of a river flow through the farm, and grazing cattle can also use these water bodies. There have been concerns about the negative impact of grazing livestock farming on water bodies. When considering sustainable grazing livestock farming, the challenge is to conserve water quality and propose appropriate habitat design to conserve biodiversity.

River ecosystem studies require a physical environment assessment and surveys of the number of organisms. The European Water Framework Directive (WFD) aims to improve all water bodies to good ecological and environmental status; the ecological assessment includes biology, hydrogeomorphology, and chemical physics assessment items. Several countries and institutions have proposed river physical environment surveys, with HABSDORE, AUSRIVAS, and SEQ-MP being prominent. RHS-HQA is a method developed in the UK (Raven et al., 1998), which has been implemented in many cases (Costa and Vieila, 2021; Stefanidis et al., 2022) and is a relatively easy survey method for obtaining information. RHS-HQA has been applied in Japan by Oishi et al. (2006) and Nakajima et al. (2010); this study used this assessment method in a stream survey in a forest grazing area.

## OBJECTIVE

This study investigated how grazing cattle use the rivers present in their pastures. A physical environment survey using the RHS-HQA was also carried out to investigate the current status of the river on the grazing land. Based on these results, the environmental design of pastureland for sustainable grazing livestock production was discussed, with particular attention to rivers and other riparian areas.

## METHODOLOGY

### Overview of Forest Grazing

The research target is the beef cattle grazing farm (K Farm), located in the eastern part of Hokkaido, Japan. The site covers an area of approximately 100 ha and includes pastureland, grassland, forests, rivers and waterways, a former cattle barn (no longer used as a barn), and storage facilities. The farm is raised with Aberdeen Angus and, as of 2020, had a stock of approximately 100 head. The pasture is open from April to November, and grass harvested from the K Farm's meadows is fed from December to March, as snow cover prevents grass from foraging on pasture. In addition, the pastures and forests are separated by roads and rivers on the property (Fig. 1(a)).

### Behavior Survey of Grazing Cattle

Fifteen sensor cameras (Ltl-6210 PLUS, Zhuhai Ltl Acorn Electronics Inc.) were installed on grazing cattle movement routes and at gates on the property to observe cattle behavior. The sensor camera was fixed at a height in the pasture, such as a tree or gate, where cattle could not reach, using a belt attached to the camera. Day and night still images were taken in infrared sensor mode. Sensor cameras have been installed continuously since 2018, but this report only presents the results of one sensor camera installed in the river (the location is shown in Fig. 1) from April to November 2020.

### River Habitat Quality Assessment (RHS) with Habitat Quality Assessment (HQA)

The RHS-HQA was conducted on the river (the S River) flowing through the K Farm. The S River is a class B river in Hokkaido, with a channel length of 19.0 km and a catchment area of 2,029 $km^2$. In this report, a 500 m section of the S River (red line in Fig. 1(a); Fig. 2(b)), where the K Farm's pasture (Pasture-R1 and Pasture-R2 in Fig. 1(a)) is adjacent, was the study site.

The RHS is a system to assess the characteristics of the river environment based on indicators of the physical environment. The RHS is carried out along the 500 m length of river channel.

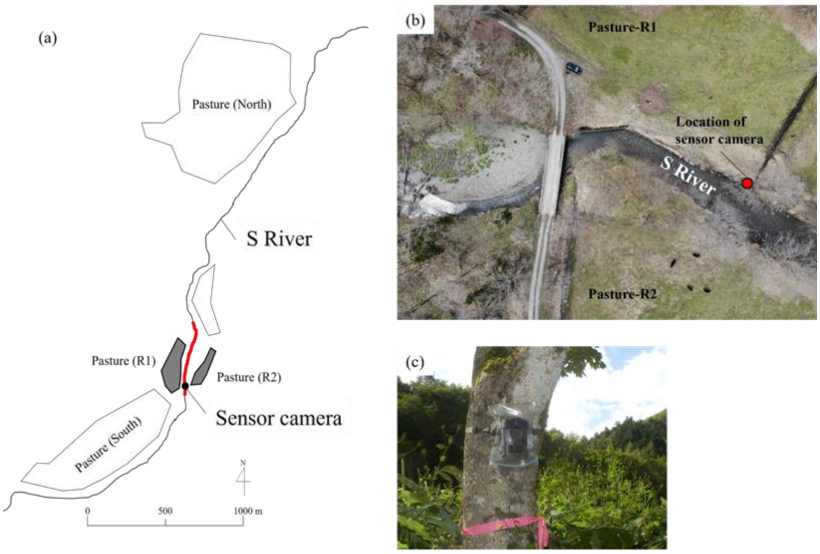


**Fig. 1 (a) Schematic diagram of the K Farm; (b) Aerial images of the target site of the RHS; (c) Sensor camera installed in a tree near the S River**

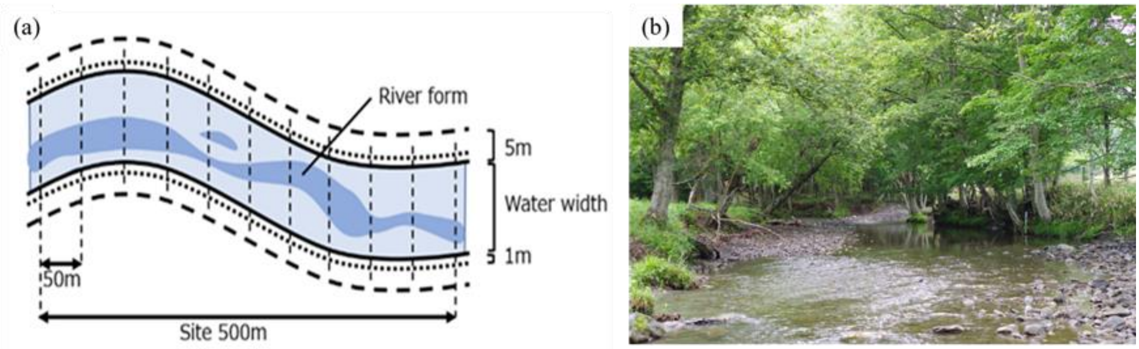


**Fig. 2 (a) Dimensions for spot-check; (b) View of the S River taken from near the sensor camera**

Observations are made at ten equally spaced spot-checks along the channel, whilst information on valley form and land-use in the river corridor provides additional context (Fig. 2(a)). Spot-checks are designed to record predominant channel, bank, and river corridor features at 10 locations spaced evenly along the 500 m RHS site. In this study, observations were made on six of the RHS survey sections (C, E-H and J). Section C records the cross-sectional shape of the river and the number of riffles, pool, unvegetated point bar, and vegetated point bar. Section E and F records physical attributes and bank top land-use vegetation structure on each spot-check points. Sections G records channel vegetation types on each spot-check point. Section H records land-use within 50 m of bank top on each spot-check point. Section J records the extent of trees and associated features of 500 m RHS site.

The results of the RHS are scored according to the HQA scoring system. The HQA is designed to assess the diversity and naturalness of the physical structure of biological habitats and is a system for assigning scores to items relating to the natural environment obtained from the RHS at a single site. The HQA gives a higher score if there are many spots with different attributes within the RHS site, or if the site has physical environment attributes that are important for riverine organisms.

## RESULTS

## Actual Use of Rivers by Grazing Cattle

Figure 3 shows the total number of daily photographs of the sensor cameras installed on the rivers took from April to November 2020. Note that the sensor camera was set up so that the sensors responded at five minutes intervals after taking a picture. Therefore, if grazing cattle stay in one location for an extended period, multiple photos are taken in an hour. Here, the total number of pictures taken within an hour was converted into one shot to investigate daily usage around the river during the grazing period. Grazing cattle were observed to move between other pastures on the property, appearing in the riverside pasture at approximately one-month intervals, staying there for about two weeks, and then moving back to other pastures. The number of days spent in each grazing area is thought to depend on the grass condition, but in 2020 the grazing areas by the river were used more frequently compared to other pastures. Next, the total number of shots by time is shown in Fig. 4. Here, the number of shots taken within an hour was directly tabulated to consider the time spent around the river. Grazing cattle were active from sunrise to sunset, with many shots taken between 4:00 and 18:00. Noon showed the highest frequency and duration of stay. Still, there was no significant tendency to use the river area at a specific time. Therefore, grazing cattle freely enter and leave the rivers while staying in the pasture around them.

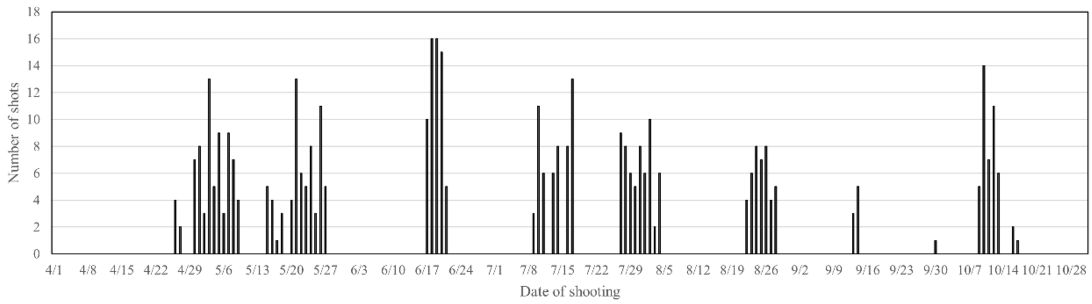


**Fig. 3 The total number of daily photographs of the sensor camera**

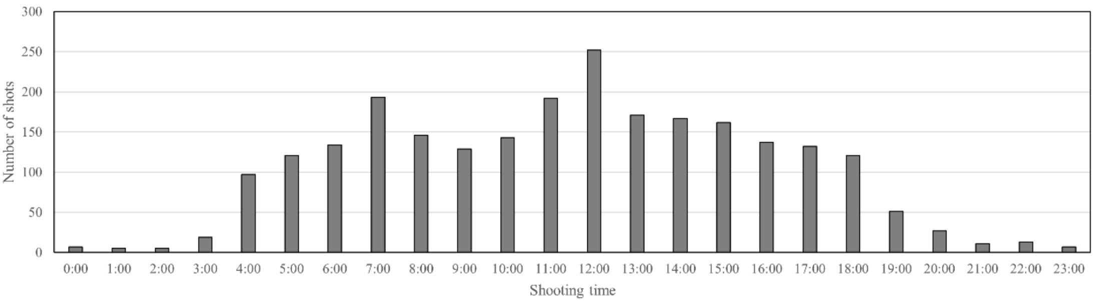


**Fig. 4 Total number of photographs of the sensor camera by time**

## Survey Results of the Physical Environment of the River in the Grazing Area

The RHS-HQA scores of the S River are shown in Table 1. The total score of the S River was 60. This score is higher than those reported for other rivers in Japan (Oishi et al., 2006; Nakajima et al., 2010) and can be regarded as a physical environment in which the natural environment is maintained. High scores in four sections were characterized: flow type in section E1, riverbed morphology in E2, bank features in E4, and land use within 50 m of the bank in H. A wide variety of flow types and riverbed materials were identified at each spot in the S River (Fig. 5(a)). The upper reaches of the S River have many meandering channels (Fig. 5(b)), and many vegetation bars and pools (Fig. 5(c)) were observed. Thus, the meanders of the river, formed by the action of the river's flow, are considered essential elements of the physical environment of the river and are the reason for the high HQA score.

**Table 1 The score of the RHS-HQA**

| Section | Categories | Attributes | Result |
|---|---|---|---|
| C | Number of riffles pools and point bars | The total number of un vegetated and vegetated point bars | 2 |
| E1 | Flow types | Broken standing waves, un broken standing waves, chaotic floe, smooth, no perceptible flow | 8 |
| E2 | Channel substrates | Bedrock, boulder, cobble, gravel, sand, silt, clay | 8 |
| E3 | Channel features | Exposed bedrock/boulders, unvegetated mid-channel bar, vegetated mid-channel bar, mature island | 5 |
| E4 | Marginal and bank features | Eroding earth cliff, stable earth cliff, unvegetated/vegetated point bar, unvegetated/vegetated side bar | 19 |
| F | Bank vegetation structure | Each bank of bankface and banktop are scored. Only simple or complex vegetation structure score. | 6 |
| G | In-stream channel vegetation | Liverworts and mosses, emergent broad-leaved herbs, emergent reeds/rushes/sedges, floating-leaved, free floating and amphibious, submerged broadleaved, submerged liner and fine-leaved | 2 |
| H | Land-use within 50m | Each bank is scored separately. Only broadleaf woodland (or native pinewood), moorland/heath, and wetland score. | 7 |
| J | Trees and associated features | Each bank is scored separately. Extent of tree and associated features. Associated features are overhanging boughs, exposed bankside roots, under water tree roots, coarse woody debris and fall on trees | 3 |


**Fig. 5 (a) Variety of flow types and riverbed materials; (b) Meandering channels; (c) Vegetation bars**

## DISCUSSION

The results of the physical environment survey showed that the S river in the pasture was maintained in its natural state, with diverse flow and bed material and a suitable bank environment for biological habitat. Here, we discuss the relationship between rivers and grazing livestock production.

First, using water troughs is a method of supplying water to livestock in grazing. In contrast, using rivers or waterways in pastureland, as in the K farm, can save labor in providing water to water troughs and allow grazing cattle to always drink fresh water (Fig. 6(a)). This can be evaluated as a synergistic effect of the river functions on the supply of livestock products by forest grazing.

Using the river by grazing cattle may have adverse effects, such as soil erosion due to trampling and bare banks due to foraging. No river repairs or other improvements were observed in the study section of this report, where grazing cattle frequently used the river. Also, there is no bare bank or severely eroded condition. One factor contributing to these is the riparian forest. The study section maintains a riparian forest of about 3-5 m in width between the grazing land and the river (Fig. 6(b)). The opening part of this riparian forest set up a cattle movement route like a gate. The riparian forest restricts the movement of cattle, and the path of movement of the grazing area of the river is fixed. This may inhibit cattle from staying in the river and inside the riparian forest for long periods, thereby preserving the river environment. On the other hand, there is also concern that the presence of riparian forest within the grazing area may represent a trade-off for vegetation within the grazing area. In R1 and R2 pastures, grass declined on the edge of the riparian forest, and an invasion of bamboo and wildflowers was observed (Fig. 6(c)). Grazing cattle did not use the part of bamboo grass encroachment during high pasture growth season from May to September. However, they have also been observed to forage for weeds in April, when pasture grasses have not grown sufficiently immediately after the snow melts, and in October and November, when pasture grass growth is suppressed due to lower temperatures because they cannot forage for sufficient grass in the pasture. In addition, forest floor vegetation in woodlands, including riparian forests, tends to be maintained even when pasture biomass is reduced due to a lack of sunlight or insufficient rainfall. The establishment of riparian forests in grazing areas may be described as securing an alternative food resource to pasture grasses.

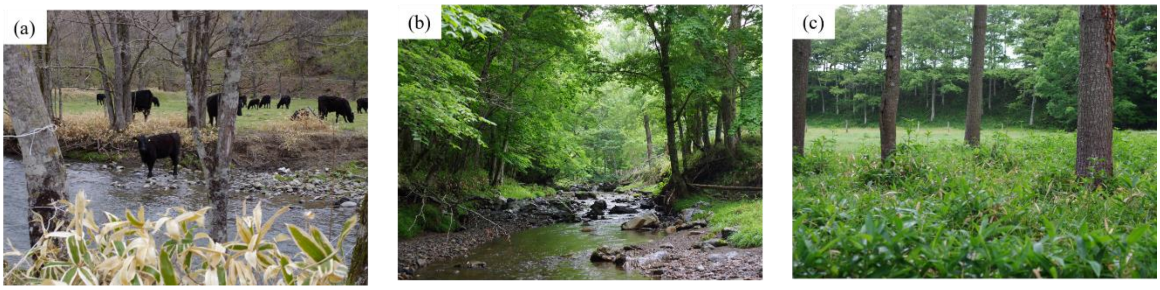


**Fig. 6 (a) Cattle using the S River; (b) Riparian Forest on the S River; (c) Invasion of bamboo into the riparian forest**

## CONCLUSION

The forest grazing of the K farm can both maintain the physical environment as a habitat for diverse organisms and use it for grazing. One of the factors contributing to this was the preservation of riparian forests. In the future, a comprehensive assessment of the river environment should be carried out, including analysis of river water quality and biological surveys. In addition, a more detailed analysis of the synergies/trade-offs of ecosystem services from forest grazing should also be carried out to accumulate knowledge on sustainable forest grazing.

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