INDICATORS FOR MIDDLE CLASS FLOOD DISTURBANCE ON GRAVEL BARS IN MIDDLE STREAM OF RIVERS: VALIDATION IN KARASU RIVER

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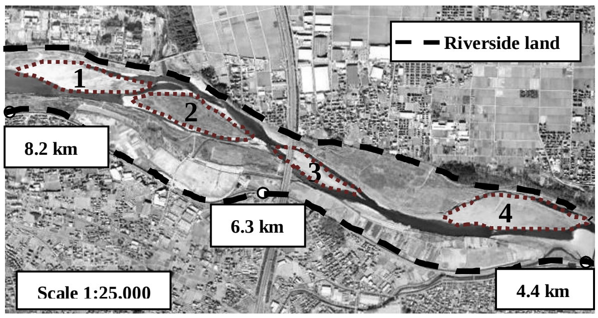
1. INTRODUCTION

Although vegetation in a river has its natural importance, sometimes it can become a problem because not only it reduces river flow capacity towards downstream but also accumulated debris of vegetation around bridge piers can increase the drag force on them while causing large scoured region around them (Melville and Dongol (1992)). Furthermore excessive forestation of a single exotic species can affect the biodiversity of the river ecosystem (Maekawa and Nakagoshi (1997)). Therefore it is important to find out what kind of flood disturbance can increase the biodiversity but control the rate of forestation on the river habitat for proper rehabilitation and management of gravel river bed. Since flood disturbance is the combined effect of flood intensity and frequency, some indices are required to define middle class flood disturbance towards above purpose. Middle class flood disturbance proposed by Connell (1978) focused on tropical forests but has not defined for the river habitat, and it has not been included in previously defined biodiversity indexes. Tanaka and Yagisawa (2012) have derived such indices to define middle class flood disturbance based on investigations on Arakawa and Tamagawa Rivers, Japan. However, since the trend of diversity of vegetation found to be different for two rivers, applicability of the flood indices needs to be checked with other rivers while finding reasons for the differences. This study is focused on confirming the applicability of those indices to Karasu River, Japan and identifying the differences, so that information can be used to design river cross section shape which can lead to proper management of river habitat with increased diversity of vegetation.

2. MATERIALS AND METHODS

2.1 Field investigation and River flow analysis

A field investigation was conducted on four gravel bars (1: 36°17'26"N, 139°4'28"E, 2: 36° 17'27"N, 139°4'25"E, 3: 36°17'26"N, 139°4'11"E and 4: 36°17'25"N, 139° 4'5"E) located at the Karasu River, Japan (Fig. 1(a)). Particle size distribution of gravel bed materials at each site was determined. d_{50} and d_{90} were estimated by an image analysis method since the particle size was found to be large at the sites where the sieve analysis test cannot be used. To simulate the river flow, a two dimensional (2D) hydrodynamic model was used. The basic equations used in the hydrodynamic model are the conservation of fluid mass equation and the momentum equations (Reynolds equation).

(a)


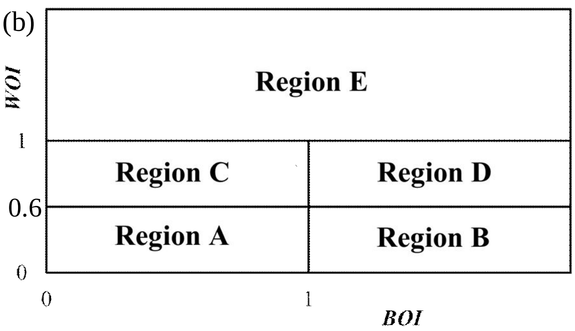
(b)


Fig. 1(a): Study area in Karasu River, Japan (distances at stations are measured from confluence with Tonegawa River)
Fig. 1(b): Classification of tree damage and washout conditions (modified from Tanaka & Yagisawa (2012))

2.2. Definition of indicators for classifying the possibility of forestation in a river

Two indices are used to evaluate washing out trees and grasses and breaking or bending of tree trunks as proposed by Tanaka and Yagisawa (2012). For evaluating trunk breakage, *BOI* (Breakage or Overturning Index = d_{BHmax} / d_{BH}) and for washing out trees and grasses, *WOI* (Wash-Out Index = τ_{*90}/τ_{*c90}) are defined, where d_{BH} is the tree diameter at the flood event, d_{BHmax} is the maximum tree trunk diameter that the flood can break, τ_{*90}, τ_{*c90} are non-dimensionalized shear stress and non-dimensionalized critical shear stress of d_{90} (grain size for which 90 % of the material weight is finer) respectively. Fig. 1(b) shows classification of possibility of plant removal or damages using the above two indices proposed by Tanaka and Yagisawa (2012). Region A-E are defined so that; when *BOI*>1 trees can be broken or bent down. When *WOI*<0.6 neither trees nor grasses will be washed out. For 0.6<*WOI*<1 only annual grasses will be washed out and when *WOI*>1 all types of vegetation can be washed out (for more details refer Tanaka and Yagisawa (2012)).

Keywords: flood disturbance, diversity of vegetated area, gravel-bed river, middle class flood disturbance
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2.3. Definition of Flood Disturbance Index (I_i) and Diversity Index of Vegetated Area (*DI*)

Considering flood disturbance and magnitude, flood disturbance index (I_i) is defined by Tanaka and Yagisawa (2012) as;

$$I_i = \int_{1/40}^{1/2} \frac{A_i(P)}{A_t} dP \tag{1}$$

Where, T is return period of flood (this study T = 2, 3, 5, 10, 20, 25, 40 years), $A_i(P)$ is the area classified in Region-*i* (*i* = A, B, C, D or E) when flood return period is T ($P = 1/T$ is the probability of flood event), A_t is the total area of gravel bar. Diversity Index of vegetated area, *DI* is defined by Tanaka and Yagisawa (2012) as;

$$DI = -\sum_{i=1}^{ns} \frac{S_i}{A_t} \log \frac{S_i}{A_t} \tag{2}$$

Where, S_i is the area of vegetation-*i*, measured by the habitat distribution map of the gravel bar, *ns* is the number of representative vegetation species on the habitat.

3. RESULTS

3.1 Relationship between flood disturbance index (I_i) and diversity index of vegetated area (*DI*) for investigated gravel bars and comparison with results of previous studies (Tanaka and Yagisawa (2012))

Fig. 2 shows the relationship between flood disturbance index (I_i) and diversity index of vegetated area (*DI*) for Region A, D and E on the four gravel bars in Karasu River (1, 2, 3 and 4), together with three gravel bars of Arakawa River (KL, KR and AR) and Tamagawa River (TO, HL and HR) of previous studies. Since the values of Region B and C are found to be small, only trend of Region A, D and E is discussed. The diversity of vegetation in Region A where plants are not washed out and trees are not broken, shows positive correlation with the increase of flood disturbance index in Karasu and Arakawa Rivers. On contrary, it is a negative correlation in Tamagawa River. On the other hand, the trend between *DI* and I_E is negative in Karasu and Arakawa Rivers, but for Tamagawa River it is positive. It can be noticed that the similar and different trends between *DI* and I_i in three rivers are due to the effect of flood disturbance that the investigated gravel bars have been subjected in previous years before 2006. (the vegetation maps used in this study were produced in 2006). From the definition, with the increase of possibility of flood disturbance, I_E increases. On contrary, I_A increases when flood disturbance decreases. As this is the combined effect of flood magnitude and frequency, I_A and I_E can be defined as indicators for middle class disturbance as derived by Tanaka and Yagisawa (2012) in their previous studies on Arakawa and Tamagawa Rivers. The diversity of vegetation in Region D where 0.6<*WOI*<1, does not show much noticeable trend for all rivers. This can be because tree types of vegetation are found to be less on the investigated gravel bars since Region D is related to the possibility of breaking or bending of trees. So this study confirms the result of Tanaka and Yagisawa (2012) and the applicability of this to other rivers, although trend of *DI* with I_i could be different for each river depending on its flood and geographical characteristics.

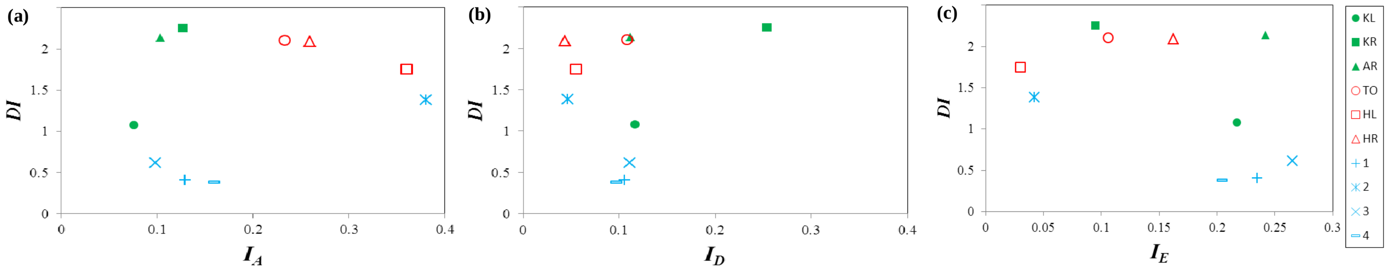

Fig. 2: Relationship between flood disturbance index (I_i) and diversity index of vegetated area (*DI*) for Reg. A, D and E

4. CONCLUSION

The relationship between diversity index of vegetated area calculated by the vegetation species map and flood disturbance index, a kind of expectation value of flood disturbance, was investigated in four gravel bars in Karasu River and compared with results of previous studies (Tanaka and Yagisawa (2012)) on Arakawa and Tamagawa Rivers. The diversity of vegetated area found to be correlated with the flood disturbance index in Region A and E and it indicates the possibility to express middle class flood disturbance for gravel bars in middle stream of rivers and confirms applicability to other rivers with that of Tanaka and Yagisawa (2012) investigated. This information can be used for designing river cross section shape for proper management of gravel bars on rivers with controlled forestation with further evaluation.

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