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Assessment of riparian buffers for reducing pollution according to land-cover pattern using RS and GIS

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Abstract : Diffuse pollution has been considering as a major source of the quality deterioration of water resources. The establishment of riparian vegetation strips or buffers along those areas of water bodies is used to reduce the threat of diffuse pollution. Remote sensing offers a means by which critical areas could be identified, so that subsequent action toward the establishment of riparian zones can be taken. On the behalf of KOMPSAT-2 satellite imagery as a high resolution spatial data, Landsat TM satellite data are used to aquire the land cover for the riparian buffers studied. This investigation aims to assess the riparian buffers established on the upper Geum river as a pollution mitigation. Through comparing the delineation of riparian buffer zones developed with the existing zones established by the government, we can find the critical distortion points of the existing riparian buffer zone.

Key Words : riparian buffers, remote sensing, Landsat TM, NDVI, land-cover.

1. Introduction

Korean government established the riparian buffer to prevent the migration of diffused pollutions from watershed to the water resource. It is reported that riparian buffers are viewed as a solution to water quality problems. Anticipated water quality benefits of vegetated riparian buffers include to remove of up to 50 percent of nutrients and pesticides, up to 60 percent of certain pathogens, and up to 75 percent of sediment (USDA-NRCS, 2001). It has, however, to be placed where they reduce the pollution loads effectively. It means that ideal position of riparian buffers locate near along to edge of water body such as streams and a reservoir. An indiscreet distribution of land use in riparian buffers leads to attenuate the function of pollution reduction. The research of the land-use pattern in the riparian buffers established has not been reached to concrete step in Korea. Moreover, It has not accounted how much does the land-use control of riparian buffers affect to the water resource. Recently, the proper arrangement of riparian buffers is studied using RS and GIS (Congalton R. G *et al.*, 2002; Narumalani. S. *et al.*, 1996). The study aims to analise land-use situation in existing riparian buffers using RS and GIS and assess land-use patterns where they are distributed for effective mitigation pollutants by riparian buffer.

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2. Methods

1) NDVI and land-cover in the study area

Currently, two kinds of riparian buffer, 1 km and 0.5 km departed from the reservoir offshore are established in upper stream catchment of Daecheong Dam reservoir. The area being limited only to the riparian buffer within 1 km along to reservoir offshore has been considered as a study area. Landsat TM satellite imagery was used to this research, which was captured on July, 1998. NDVI (Normalized Difference Vegetation Index) was used to analyze effectively density and distribution of vegetation. NDVI was calculated by band3 and band4 of Landsat TM. Eq. 1 is a general formulation of NDVI. It ranges in -1 to 1.

$$NDVI = (\rho band4 - \rho band3)/(\rho band4 + \rho band3) \quad (1)$$

Land-cover was classified to get the surface situation of the study riparian buffer established. And then the classification results are used to identify land use pattern. Classification was conducted using the method of maximum likelihood. For the convenience of taking into account the different soil chemistry of agricultural cultivations between paddy plots and uplands, the field of agricultural cultivations was divided into a upland as a diffuse pollution source and a paddy as a wetland with the function of pollutant reduction. Region of interest (ROI) for classification validation includes 1,524 pixels which are sampled from the regions convinced as water, forest, building&road, upland, paddy, barren&sand respectively. Those six land use categories are selected to represent a land cover situation of the area. An error matrix was used to estimate the accuracy of land-cover classification. Overall accuracy and Kappa coefficient (Khat) are determined using several references such as a white map with 1:25,000, KOMPSAT-1 EOC imagery.

2) Analysis of land-use pattern

Riparian buffers have a function to protect a direct inflow of the pollution from these area to the water resource through physical, biological, and chemical processes. So, it is understood that an ideal arrangement of Land-use is pollution area, vegetation area (buffer zone) and water resource in order (see Fig 1-a). In terms of effective reduction of pollution migrated from upland, the existing land-use pattern in the riparian buffer was assessed. To analyze the riparian buffers, two basic processes are applied to prepare the catchments that are compared with each other in terms of the land-use characteristics. First of all, five kinds of riparian buffer strips alternatives with 50m, 100m, 300m, 500m, and 1 km distances, respectively from the offshore of the reservoir are built. These alternatives are prepared by dividing the existing riparian buffer with 1 km distance. And then, the study watershed including the riparian buffer established is separated to two types of sub-catchments based on the discharge pathways of pollution from sources into the water resource. Two sub-catchment alternatives are sorted by two types; a direct discharge catchment alternatives and an

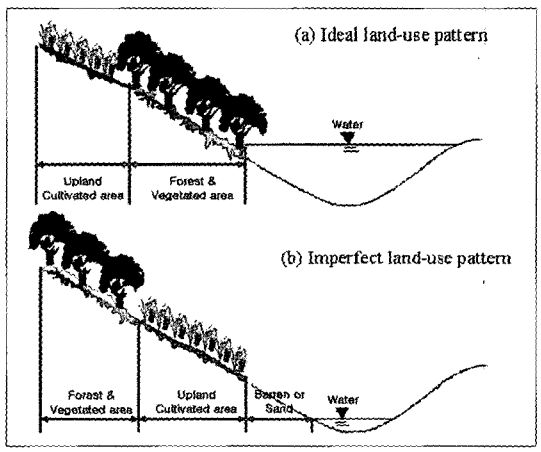


Fig 1. land-use patterns for riparian buffer.

indirect discharge catchment alternatives. As shown in Fig. 2, seven direct discharge sub-catchment alternatives named "zone 1 to zone 7" and an indirect one named "zone 8" are prepared in this study. After implemented two basic processes, the results are overlapped. Namely, pollution migrates along a tributary stream into water resource in an indirect discharge one. On the other hand, pollution comes into the water body through a riparian buffer in the direct discharge one. The pollution reduction efficiency of tributary water by a riparian buffers is low because of a relatively short contact time between pollutions and vegetation strips. Whereas pollution conveyed from direct discharge catchment can be removed effectively by riparian buffers because of this catchment has longer interface between riparian buffer strips and water body. GIS spatial analysis technique was used to build up alternative riparian buffers with different distance.

3. Results and discussion

Although the NDVI shows that the more it is dyed red the better vegetation is developed as shown in Fig. 3, it is difficult to differentiate clearly the areas between upland cultivation area asa pollution source and wetlands or paddy plots as a pollution reduction area from the same vegetation area.

On the other hand Fig 4, which is resulted from land-cover classification, provides a detail of the information about land-use pattern in the riparian buffers studied. Accuracy of the classification was 97.97% of overall_accuracy and 0.96 of Khat.

Fig. 2 shows areal ratios of five land-use categories to the area of riparian buffer alternatives made with

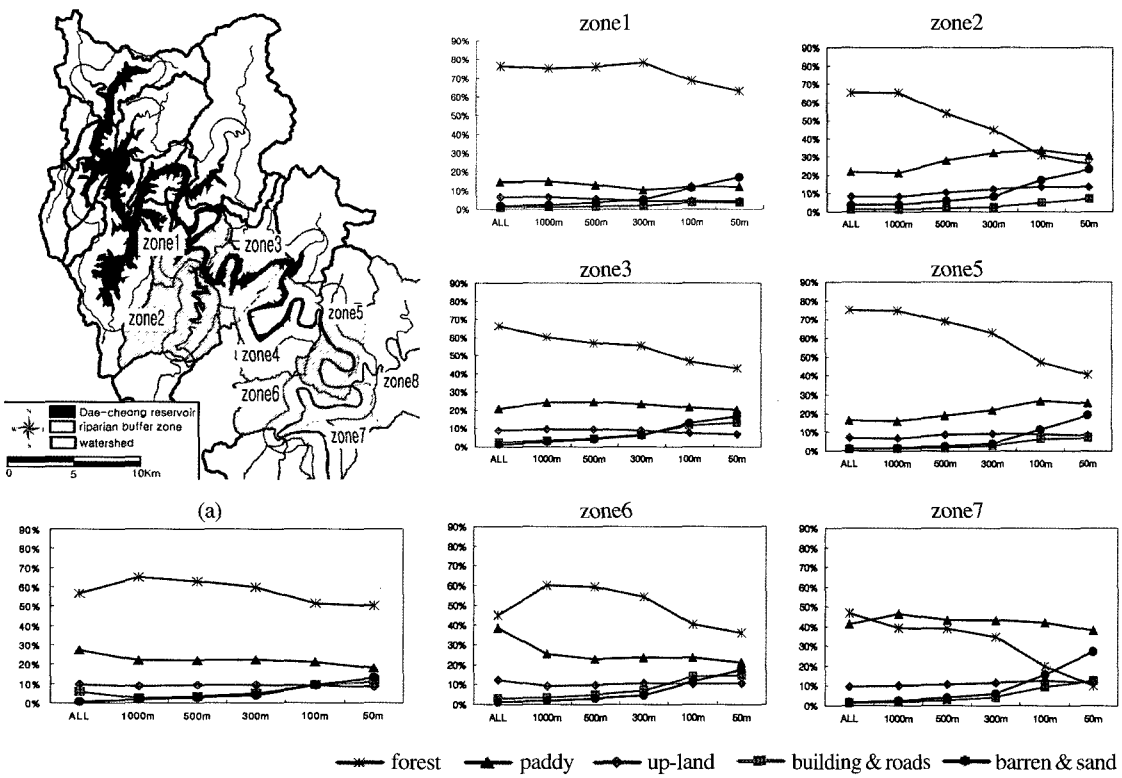


Fig 2. Result of land-use pattern analysis.

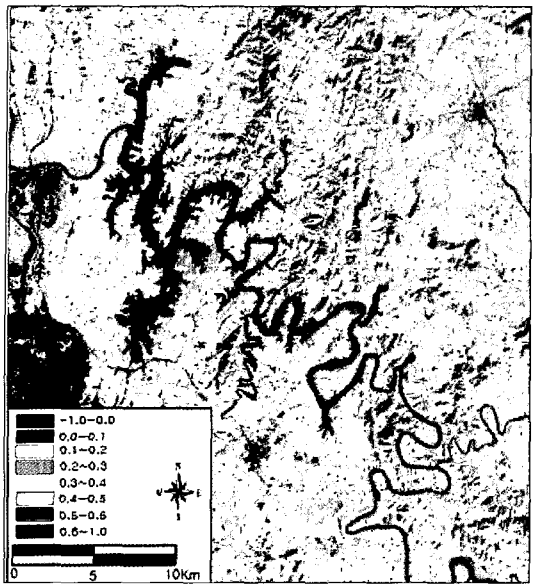


Fig 3. Result of NDVI analysis.

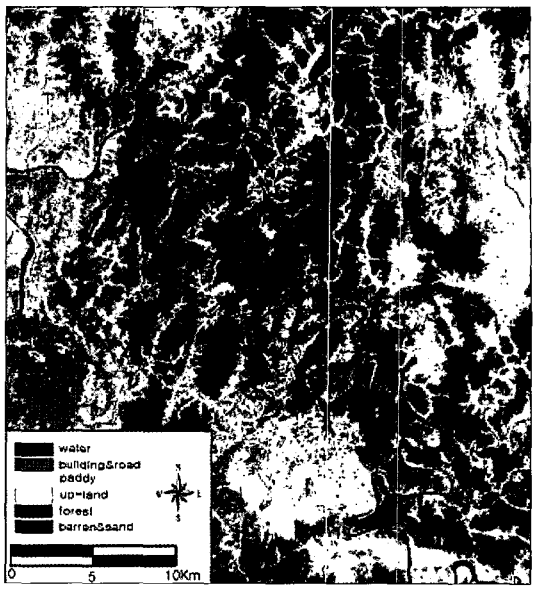
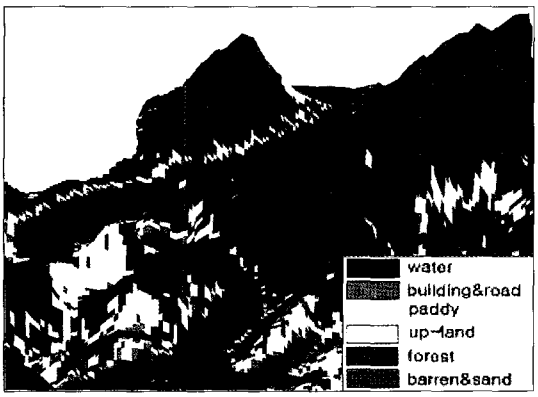
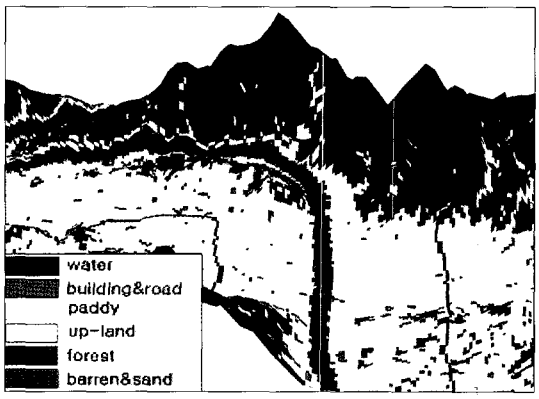


Fig 4. Result of Land-cover classification.

different distances from the edge of water body. Beside Fig. 2-a, which denotes the change of land-use areal ratios to total area of the riparian buffer established by government, others show that land-use distributions in six subcatchment alternatives out of eight zones in the figure. From Fig. 2-a, it is found that the ratio of forest area of total Daecheong Dam reservoir watershed, indicated in the table as the term "all" is less than that of the riparian buffer established. The more distance is, however, close to the stream the more forest decrease in the ratio of area to the stream and increase in pollutant area such as building&road, barren&sand and up-land cultivated area. It means that lots of pollutants such as residence or commercial area including leisure facilities, roads for approaching there and upland cultivated area are distributed near the stream in riparian buffers. Paddy area occupies about 30% of total area of the watershed. But it decreases to about 20% in the 1 km riparian buffer. There is, however, no evidence of significant change of paddy areal ratios in the riparian buffer as well as upland. It is considered that the convenience to



(a) Ideal land-use in Riparian buffer: Zone 1



(b) Heavy exploitation in the Buffer: Zone 7

Fig 5. 3-D images of typical land-use arrangement.

cultivate agricultural products like accessibility and gentle slope of fields and the easiness to secure irrigation water leads to the sustainable cultivation in the area in which riparian buffer established. All of eight zones in Fig. 2 show that pollutant increases typically in under 300m of riparian buffers. Zone1~7 are direct discharge subcatchments and zone 8 is indirect one without the effect of pollution reduction by riparian buffers. Especially barren&sand area reverses forest area in zone7. It is caused that many developed area placed near Dae-cheong reservoir. Fig 5 is the special subcatchment sample of the 3D image for the existing riparian buffer. The land-use pattern of zone 1 is a ideal so that forest and paddy areas are extensively distributed on the offshore part of the riparian buffer. It is also expected that zone 1 reduces effectively the migration of pollution loads before coming into the water resource. According to the decrease of water level of the reservoir, the deforested water front area is appeared with a linear area as a barren & sand zone in Fig. 5-a. As shown in Fig. 5-b, there is a heavy exploitation on the riparian buffer in zone7. Roads are developed along the waterside and cultivated land, especially up-land area is located near the water body without buffers. The effect of pollution reduction can not be anticipated in this zone. It is strongly needed the regulation of land-use in the riparian buffer. Basis on this result, the study using high resolution KOMPSAT-2 imagery would promise to improve assessment resolution of riparian buffers much effectively.

4. Conclusion

This paper assesses whether existing riparian buffers are established effectively to mitigate pollution inflows to drinking water resource, Daecheong Dam reservoir using RS and GIS. Incongruent land-uses for a riparian buffer e.g. buildings and upland cultivation locates in the buffer zone. Spatial arrangement of land-use is unsuitable for mitigating pollution inflows. The buffer is incompetent for the inflows from major tributary catchment of which riparian buffer affords to cover the foot. It is recommended that riparian buffers have to be arranged along to the riverside of small tributaries rather than main stream.

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