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博士の専攻分野の名称	博士（学術）
学 位 記 号 番 号	博理工乙第 224 号
学位授与年月日	平成 27 年 3 月 24 日
学位授与の条件	学位規則第 4 条第 2 項該当
学 位 論 文 題 目	FACTORS AFFECTING FORESTATION IN THE DOWNSTREAM REACHS BELOW A DAM （ダム下流の樹林化の要因分析）
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論文の内容の要旨

Rivers and streams are among the most world's valuable and diversified ecosystems that have been seriously altered/ affected by means of human activities, particularly civil engineering works including barrage construction near river mouths, dam construction across rivers, gravel mining, channelization, and other regulation measures. Vegetation in rivers channel and flood plain creates a valuable natural environment and maintains a dynamic ecosystem. The spatial distribution of flood plain vegetation is strongly dependent on the flood system, particularly flooding, river bank erosion and sediment deposition, and the regeneration of riparian vegetation. Construction of dams, their decommissioning, and sediment flushing from the reservoir have been associated with vegetation dynamics in many studies. The increase of the amount of vegetation as well as forestation immediately downstream in the interval topical dam could potentially illustrate the changes in the amount of vegetation at longer distances from these dams. There is not much available information on the longitudinal impacts of dams on vegetation, such as how far downstream and the degree of regulation to which a dam on a river can influence riparian woodlands.　However, factors governing the spatial changes of forestation in the floodplain after dams have not been explored extensively. It was hypothesized that, magnitude of forest coverage (FCR) of downstream varies due to dam type, the hydrological and climatic factors. It was assumed that effect of dam on downstream forests diluted with distance and the spatial pattern of forestation affected by the land use of the river channel and catchments.

In this study, we examined the interacting effects of dam and land use on the vegetation/ forestation changes in dams' downstream along with land coverage systems in the river channel floodplain. we used freely accessible Google Earth® (GE) satellite images in high spatial resolution as direct data resources to explore potential uses of land use/cover area. Different land use areas were determined within the study area from an appropriate aerial (above ground) viewing height (or zoom) for making visual vegetation cover fractions using Google Earth® is 50-100 m. Spatial land coverage data was obtained from April to December 2013 using available images from Google Earth® (version 7.1.2.2041) (http://earth.google.com). We used the Google Earth® polygon creation tool to estimate land use as well as vegetation coverage area in the flood plain channel zone because it allows a more accurate interpretation of images by controlling distance and work scale alignment. The data was calculated by making segments from the dam to the first tributary, from first tributary to second tributary, from second tributary to third tributary, and so on. The tributaries entering the main river channel were considered by the number of inflows. The data was calculated on the parameters were classified as follows: forest covered area, grass or herbaceous covered area, agricultural area, sports area, wasteland area, sandy or gravel area, total area and water area in the river channel, sandbars and floodplain. Downstream data was calculated for about 25km following the dam, which varied in some cases based on the distance to the ocean. Dyke distance was measured in the river channel crosswise by the Google distance calculator in each segment, taking an average of more than 10 times/points. Data on maximum and minimum river stream flow rate (m^3/sec) was collected from the Global River Discharge Database. In case of Japan, the hydrologic data were collected from the latest statistical year database provided by Ministry of Lands, Infrastructure, Transportation and Tourism, Japan.

The downstream forest coverage ratio (FCR) of flood control dam is not significantly different from that of hydropower and multipurpose dams but it is significantly different between hydropower and multipurpose dams ($p<0.01$). Because there is no significant difference between flood control with multipurpose dams while hydropower are significantly different from flood control and multipurpose dams in relation to discharges flows ($p<0.01$) from dam. The rivers which have lower difference in maximum and minimum flows ensure sufficient water is available for environmental needs and forest development. The systematic approach is to restore more naturalized in stream flow patterns to allow natural recruitment and growth processes. Differences in flood frequency, duration, and intensity are the most important factors controlled by physical attributes of the river and its floodplain such as water volume, channel shape, and slope of the river bed that determine differences in floodplain forest vegetation. Dam is disrupted the natural process of rivers flows which affects the morphology of the riverbed, downstream floodplains. That's why, downstream forest as well as vegetation coverage ratio is not significantly changed by the slopes of the rivers.

The climate exerts the dominant control on the spatial distribution of the major vegetation types on a global scale. In our study, we used Koppen's climatic classification system and observed that temperate forest is associated with cold climate forests but it is significantly different with tropical and dry climate forests and also different between tropical and dry climatic zones ($p<0.01$). Climate, in the given context defined as a seasonal course of solar radiation, temperature, and precipitation, primarily determines the predominant type of terrestrial vegetation. Forest development is the highest just below the dams, and the ratio of forest cover decreases with distance from the dam toward the river mouth. The forest coverage ratio shows a strong negative correlation with distance from dam. As for example in Japan, Forest covers almost 55.63% with a maximum up to 80% of the total area of flood plain just after dam and when go to downstream about 20 to 25 km which rate is below 20.43 % of the total flood plain area for all types of dams. On the other hand, herbs coverage ratio shows opposite trend of forest coverage ratio for all types of dams. Similar results of variation of forest coverage between dam segments and distant downstream also observed in South and North Korea, European countries, Southern African countries and worldwide all other studied dams.

Forest coverage ratio was found to decrease with an increase in dyke distance, number of inflows ($r=-0.66$, $p<0.01$) and water coverage ratio, and bare land in the river flood plain. Just after dam as the flow number is reduced forest coverage ratio is high and with increased number of inflows this ratio reduced. A strong negative correlation is found between number of inflows and forest coverage ratio towards downstream. From dam to downstream, number of inflow increases which has a great impact on forestation as well as vegetation. Forest coverage ratio is very small when more than 13 number of inflows entrance to main channel in compare to forest ratio of dam segment where flow only comes from dam.

It is found that just below dams, agriculture area is less compare to downstream but it does not have a significant trend with forest area. As for example in the downstream of European studied dams, forest area is larger below dams (35-75%), where there is no or very little agricultural land (0-2.5%). In the case of some dams, e.g. Eguzon, Mohne, Spremberg, Barrage dela Roche, and Solinia, though the forest coverage ratio is high (about 80% of the flood plain area), 0-0.9% land is used for agricultural purposes. Forest coverage ratio is not significantly correlated with the increase in sports areas in the flood plain. The relation between forest coverage ratio and wasteland area ratio is not strongly but negatively correlated. However, progressive measurement downstream, where agricultural area, sports area, wasteland area increased, revealed a reduction in forest coverage in the flood plain. Moreover, sandy or gravelly area exposure is very small just below dams (e.g. South Korea 20%) due to large forest coverage and towards the downstream reaches, sandy or gravelly area covers larger portion of the river basin (e.g. South Korea 45%), which reduces forest area in the flood plain.

Catchment areas' land use pattern strongly influences river channel forestation after the dams. It was observed that there is a distinct difference of land use system among the catchments. As for example, in Zimbabwe, the highest average forest coverage (60%) is found in downstream reaches of the Mazvikadei dam, and the land use in its catchment is 3.96 % urban, 4.24% agricultural, 16% bare land (including 6.69% wasteland and 8.92% sandy or gravelly land). The lowest average forest coverage (30%) is found in the Kariba dam (in Zambia) flood plain, where the catchment land uses are 10.88% urban, 0.96% agricultural, and 31% bare land (including 12.58% wasteland and 18.51% sandy or gravelly land). Similar results of variation in the land use pattern of the catchment are also found for all the other dams.

However, a principal component analysis (PCA) showed that the proportion of bare land in the catchment area, the dyke distance of the river and the number of inflows or tributaries are the factors most associated with forestation among the studied parameters. Forestation progressively decreases following the entrance of free following tributaries after dams, which appears to reduce the effects produced by dams on vegetation as well as forestation by causing local deviation. The impact of different land use types, such as agriculture on forestation, is insignificant though in some cases, land use areas cause of forest area reduction. Our results suggest that when it comes to determining river management goals, care must be taken to understand the downstream vegetation dynamics due to the effect of dam and catchment land use pressures regarding environmental impact assessments and biodiversity concepts in riparian zones.

論文の審査結果の要旨

わが国の河川では、近年河道内に大量の樹木が生え、河川景観を大きく変化させてきている。河道内に植生が繁茂することは河川景観の変化にとどまらない。河川生態系は本来、頻繁に洪水が発生することでそれが撹乱となり、様々なパイオニア種の生息を支えてきている。ところが、河道内に植生が繁茂することは撹乱の強度を低下させ、河川生態系の性格を変えるために生物多様性の維持に大きな影響を与える。また、洪水管理という視点で見ても河道内の樹木の増加は、洪水疎通能力を低下させることから大きな問題である。ところが、わが国の河川における近年の樹木の増加の原因は必ずしも明らかになっているわけではなく、他の諸外国の状況も不明である。そうした中、ダム建設が河川の樹木の増加に関係しているのではないかという仮説がいわれてきている。ダム建設はわが国に限ったものではないことから、もしもこの仮説が正しいとすれば、諸外国の河川も樹木で覆われていることが考えられる。こうした背景の下、本論文は世界中の河川を対象にダム建設と河川の植生の増減との関係を著したものになっている。

研究では、グーグルアースを用いて衛星画像から、河川区間における河道内陸域の土地利用の面積をダム地点から流入する支流に区切られた区間ごとに読み取ったものである。これを全土地利用の面積で割った割合について議論を行っている。土地利用については、樹木群落面積、草本群落面積、畑地、スポーツグラウンド等に分けた解析を行っている。

分析したダム数は、グーグルアースで十分鮮明な画像が得られるものとして、日本50、中国30、韓国10、北朝鮮7、ベトナム5、インドネシア3、スリランカ4、バングラデシュ1、インド20、タイ14、ミャンマー4、ポルトガル3、スペイン3、フランス3、ドイツ3、ポーランド1、スロバキア1、チェコ1、ロシア4、アメリカ合衆国16、メキシコ7、カナダ6、南アフリカ7、ジンバブエ3、ナミビア2、アンゴラ1、ザンビア1、モザンビーク1、タンザニア1、オーストラリア14、チリ1、アルゼンチン3、ウルグアイ4、パラグアイ1、ブラジル3に及び、ほぼ全世界を網羅したものになっており、概ね世界中の傾向を得ている。

解析においては、まず、樹木群落面積率をダムからの距離の関数として分析している。結果では、ほぼ全てのダムにおいて樹木群落面積率はダムからの距離とともに減少していることを得ている。また、流域からの流入支川数によってもこの減少関係が変化するものではなく、樹木群落面積率の減少は単に距離ではなく流入支川によって生じていることを示唆している。

草本群落面積率は、いずれの地域においてもダムからの距離とともに増加傾向にある。さらに、樹木群落面積率と草本群落面積率との関係を見ると、いずれの地域、ダムの形態についても負の関係にある。しかし、これは草本群落面積が単純に樹木群落の面積に置き換わったものではなく、樹木群落面積の増加に対して、草本群落面積の減少はその半分程度になることが得られている。これは、樹木に覆われることで草本群落が減少するのではなく、それぞれの別の要因に依っていることを示している。

次に、ダム下流における平均の樹林群落面積率について調べている。まず、洪水調節ダム、発電ダム、多目的ダムといったダムの機能別には大きな差はみられないことを示している。また、樹木群落面積率、草本群落面積率共に河道勾配との関係はみられない。しかし、気候区別では、樹木群落面積率は温帯及び冷帯で有意に高く、熱帯及び乾燥地帯では有意に低くなっている。

次に、ダムの場合と同様に、堰について、堰からの距離とともに樹木群落面積率の変化を示している。樹木群落面積率は、いずれもの場合も堰からの距離とともに減少することが示されるものの、ダムと異なり100-200m程度の間に急激に減少することが示されている。また、この減少率は堰によって大きく異なっており、堰のその時の状態が大きく反映することが示されている。

論文は5章から構成されている。第1章の序論に続き、第2章で方法論を記述、第3章では結果が記述されている。結果は大きく5つに分けられ、3.1でダムの用途別で樹林被覆率の変化、3.2で樹木群落面積率とダムからの距離との関係、3.3で樹木群落面積と河道内の土地利用との関係を記述している。次に第4章で考察を行い、第5章で結論を記述している。必要となる参考図については巻末に補遺として挿入している。