Eco-contagious: bringing urban riverscape into sustainable urban landscape

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Abstract. Nowadays, many cities develop their facilities, technologies, architectural, or even “starscape”. Rarely had urban area consider their ecological perspective into design practice mainly in tropical developing countries. In developing countries, river condition today has been deteriorating; thus, it will impact to the ecological continuity fragmentation. Bogor itself has the oldest Botanical Garden in Indonesia. It has richness in biodiversity, both plantations and animals. Nevertheless, there is a Ciliwung River break through the middle of the area, along the way to the Capital City of Indonesia, Jakarta. This study aims to find a new model of urban riverscape principles in a setting of urban area. The analysis had been done in this study, including river sinuosity calculation, corridor connectivity calculation using geographic information system (GIS) through list cost path analysis, and also finalized with designing the public and private open space as strategies to bloom the ecological aspect across the region.

1. Introduction
The development of the cities are becoming regular occurrence and this issue is causing a range of problems such as natural and social aspect, particularly the devitalization of the natural environment in an urban setting. All cities in developing countries especially Bogor, dealt with this constraint thus, urban landscape clearly requires some strategic intervention. The city is at the upper area of greater Jakarta the capital city of Indonesia. In there, heritage building still can be found with a vast greenery exposures known as Bogor Botanical Garden (BBG). This BBG is also passed by the main river-Ciliwung River-in the city which makes the landscape dynamics inside it, even more, varies (Khrisrachmansyah, 2018). On the other hand, there are severe negative impacts of development particularly in the riverbank. One of the problems that Ciliwung River transports around 5–17 tons per year of the quantified pollutants into the Java Sea (Dsikowitzky, 2018). Therefore, both the governments and people should clearly consider the role of sustainable urban water. Urban water including natural and man-made activities and both of them will support the economy. Water in urban area is a spatiotemporal distribution and
possesses renewable, economic, and ecological functions (Davies, 2014). The functions of the urban water environment are mainly associated with water security (i.e., flood regulation), water resources, water ecology, water landscapes, water culture, and water economy. Furthermore, the foundation of sustainable urban water is the natural water environment (Huibin, 2017) that contributes to the efficient economic water environment and healthy social water environment (Martinezpaz, 2014). This study reveals a landscape architecture approach which considers the natural water environment as the most significant influence, thus can effect the social and economic aspects of the people.

However, the condition of Bogor City itself is the lack of connectivity within its natural environment. Although Bogor City has a marvellous BBG, the structure of the natural system is not connecting between settlement and natural features. Furthermore, there are several slum areas along the river-Ciliwung nearby the BBG that have not had interventions of the urban landscape through an ecological approach. One of the areas is Pulau Geulis, which has several problems including landslide, water pollution, waste, and dense population. One of the best approaches in the urban river is to make ecological connection. This means the river should absorb urban rain or precipitation. This can significantly achieve five ecological goals comprising of water source protection, ecological corridor construction, water storage, and flood discharge, water purification and ecological river landscape (Gao, 2017). The way so far has been a stumbling, incremental process, fraught with conflicts of politics and economics, especially in urban ecology that has brought us to where we are now. Landscape ecology through planning and design approach is a good idea that has gotten bigger and better.

The aim of this study wants to:
1. Create an ecological corridor based on greenery area and
2. Designed green open spaces that provides and applies sustainable values for the city.

Usually, GIS is using in several disciplines such as geography, soil science, geology, and urban and regional planning as well. Thus, landscape architecture can have a beneficial by using this approach. After analyzing the potency of the study location, design approach applied to boost the spatial quality of the Pulau Geulis. Moreover, the contagious concept can be applied in the field of urban riverscape at Pulau Geulis, Bogor Botanical Garden, and Lebak Kantin, so those areas possibly linked as an ecological corridor.

2. Methods

This study originally a result of the student competition, located in Bogor, held by the Indonesian Society of Landscape Architect (ISLA) in 2017. Furthermore, the product has not been written in academic transcription. Hence, this study reconstructs and added more several knowledge to consider in especially the principle of ecological approach as an outcome. The methods that used was research for design which had process as follows: (1) observation or site visit in the study area; (2) GIS approach (i.e. least-cost paths (LCP) analysis) of the landscape; (3) sinuosity calculation; (4) superimposed; and (5) green open spaces design in several locations that appropriate to be upgraded through ecological approaches. This study conducted in Ciliwung River through Bogor, West Java. Site study area included Pulau Geulis, Bogor Botanical Garden, and Lebak Kantin until Peranginan Park, all these area set-ups in the riverbank of Ciliwung.

First, observation/site visit in the study area has been done for several days. Data collection of plants, animals, figure-ground, and potential of the green open space both private and public ownership also have been established on site. This first step wants to see all open spaces and green open spaces in the study area. In the field, data were recorded by geographic positioning system (GPS). Second, GIS approach was used to analyze and generate the green corridor around the site location. Data Landsat collection became one of sources to consider the proportion and distribution of natural area and the green open space in Pulau Geulis. Afterwards, studio analysis was conducted using GIS approach focusing on image satellite analysis. From there, data processing was taken with least-cost path analysis. The least-cost paths (LCP) method is one of the simplest resistance-based models that could be an excellent candidate to spatially identify areas where movement is potentially favoured in a given landscape (Balbi, 2019). The result was to identify the significance of connection between natural area and urban parks.
The LCP was used to connect several patches in one line which has the most efficient one as a spatial analysis tools in ArcMap. There were several steps to do as follows: (1) input all observation data. This data consist of mark point from geographic positioning system (GPS) of potential open spaces. The criteria of potential open space were having large spaces, trees or vegetation, and a lot-of people come and used. (2) input the Landsat map and took band of 5 and 4 which were the NDVI data. NDVI is the normalized difference vegetation index which has visible spectrum and commonly depict live green vegetation. (3) reclassify the NDVI so that the image can be separate in several groups. (4) Cost distance tools was used to read the direction. (4) Cost back link and cost path tools were used to finalize the direction. The map of LCP can be seen in figure 1. The result of this process is a line that represent the most efficient one, among several green open spaces.

![Figure 1. Map of LCP: cost distance, cost back link, and cost path (from left to right)](image)

The third step was sinuosity calculation which has purposes to figure out which part of the river in Pulau Geulis is safer for people and which parts of that area are available to be conserved as natural areas. The sinuosity can be calculated with the formula that can be seen in figure 1. The basic patterns described here are straight, meandering, braided and branching. Predominantly single-thread streams are defined as either straight, sinuous (gently meandering), or meandering by ratio between length of perpendicular (AB) and length of the bend (CD) (Allen, 1970).

![Figure 2. Sinuosity calculation](image)

Later, the river with radius 750 m from site was determined to be the part of sinuosity calculation. Next, it was divided into 15 plots with 400m2 area. Each plots had different radius and tangent on its shapes. By calculating its ratio between length of bend and straight lines in between the bend resulted sinuosity value. It believed that higher value will have better ecological value then the straight one.

After categorized the ratio, analysis result were superimposed (i.e. LCP and sinuosity calculation). In this phase, the decision whether the areas are available for the public or natural area were taken. The natural areas referred as high ecological sensitivity value, while the low ecological sensitivity decided for the public parks. The least-cost path result was used to cut the number of potential open spaces.
The final step took the longest process because the team developed design as tools for research. In design process, the draft of the concept were explained and expressed in the pattern of design. This step was on the green open space phase (figure 3). Then the team were cross check and site visit again to reconsider the pattern whether the design available or not. This second step of cross check also being a final filter process of how many open spaces that can be designed. Then, the final design or model of eco-contagious was implemented. The all process of this study can be seen in figure 3.

3. Result and Discussions

3.1. Observation in the study area
The results of the eco-contagious process are explained as follow. In the first stage, based on observation, there are several problems and site potential. It consisted of physical and social aspects. The physical aspects comprising of waste problems, landslide, high density, and lack of green open spaces both in private and public spaces. On the other hand, there are several potential attractions in the study area which containing home gardens that can attract birds, insect, and other animals. The social cohesiveness has already established in the study area. This condition occurs because of the high density of settlement and local people always using small space to gather. This study not profoundly explores the social strategies; nevertheless, it considers the public spaces as gathering spaces and social places.

Figure 4 depicts several potential open spaces in the study area. There are 11 areas of green open spaces and public open spaces. The open spaces characteristics can be divided into two main
characteristics there are natural area and the others are community spaces. These spaces have observed with consideration of availability that has access, a range of vegetation that can attract birds, and intensively which people can gather. On the other hand, there are several ecological aspects to consider where open spaces play a critical role to make a corridor for the animal, especially birds. In the urban landscape, there are terms that consist of blocks (patches), corridors, and matrices. Those are the basic model of landscape system that contributes to the composition of the landscape (Zhang, 2017). This theory could be implemented in riverscape as a natural urban system, which Bogor Botanical Garden as a source of block (patch), the settlement and its development as matrices, and riverbanks as a corridor. In other words, there are stepping stones among matrices and corridor that can be some available open spaces or green open space. These stepping stones can be potential open spaces that scattered among the study area. Those landscape system can be a platform to construct the sustainable urban landscape through planning and design.

3.2. The GIS approach, LCP analysis
At the second stage, the GIS approach, LCP analysis is used. As explained in the methods, Landsat imagery is the main input for this analysis. After that, the map is overlaid between observation data (GPS data) and The normalized difference vegetation index (Landsat-NDVI) map.

The aim of this process is to determine which one of the open space has relative biomass (greenness) that considering the availability of the spaces after surveyed. Next, this overlaid-map was calculated through least-cost path analysis. The output of this process is a raster dataset. This is a raster dataset that calculates the patch or locations from which the least accumulated cost distance for every output cell location; in other words, a raster dataset depicts a way in which one is the least costly source among open spaces. This is why the study expresses the concept of ecological contagious that reveals the ecological connections between green and public spaces. In figure 4 (right) there are 11 areas that have potential open spaces where can be developed. These 11 areas are the result of the observation.

3.3. Sinuosity calculation
The third stage is sinuosity calculation. Picture 5 illustrates the characteristic of sinuosity in the study area, which has a level of ecological sensitivity. The highest value of ecological sensitivity is segment 2. This area is designed with conservation approach which available for birds and other animals to get their food; in other words, this area is altered for supply and provide all kind of nutrient for animals. On the other hand, there are four areas which are medium in the level of ecological sensitivity including of segment 1, 7, 9 and 10. The rest, for 9 places are in the low level of ecological sensitivity. The areas that have a medium level are designed with open space that equal in conservation and human activity. However, the low level can be designed and provided by a range of human activities, such as gather and held several events. Furthermore, the spaces that have a low level of ecological sensitivity should also be protected by alleviating interventions about the settlement.

In addition, from the table, it can be summarized that in urban areas, the level of the sensitive area becomes high if the number of sinuosity is more than 1.2, while if the number of sinuosity is under 1.1, the ecological sensitivity will be low. In this study, the medium level of ecological sensitivity tends to high regarding the significant demand for ecological services. Therefore, the four areas in the map show that better if those areas designed with more purpose for ecological approaches.
3.4. Designing the green open spaces
At the last stage, designing the green open spaces, figure 6 shows the design of each potential space that consisting of a range of vegetation and facilities, so that people can gather and take their relaxation. Every space has its own characteristic depends on sinuosity analysis. The north one provides for nature conservation, which the vegetation varies. This result of design has been recheck to the field, because several area are not appropriate, sometimes the site is too small or narrow as social space, located in the cliff, and cannot be accessed directly. Therefore, there only four best open space that can be designed and proposed as corridor, patches for social space, and natural/conservation area.

About the concept, there is a uniquely powerful concept in this study, as planning principles, the contagious term is used in this study. Contagious in this study means that green corridors are established in several possible area of green open spaces, considering least-cost paths, and sinuosity calculation. The contagious has a spirit of flourishing the source of Bogor Botanical Garden to its surrounding along the Ciliwung River. This concept exhibits the ecological corridor that is able to connect all of the natural areas and green or public open spaces in the study field. Another approach is the design principle which is using birds’ movement and behaviour. In addition, the types of birds morphology/anatomy also considered in the design pattern.

In the design approach, there are several schematics to consider in, including mimicry of the anatomy of a bird. This open space has a pattern of Paro or beak of a bird. Furthermore, this area aims for the home of birds. In the middle of the Geulis Island, there is an existing home garden that redesigned as larger open space which aims for food and fun both people and animal. This open space has a design pattern of a bird’s claw. Another open space is at the southern area, which also has the same pattern from the previous one. Furthermore, these areas are representing the stepping stone of an ecological system. The last is the southeast area of the Pulau Geulis that has a function for pedestrian ways designed by a bird’s wing pattern. This open space is representing as a corridor in the ecological system. The ecological system can be applied through greenway in urban river system of the study area. Thus, the
river greenway has the potential to become the backbone of the green space system in the future (Sun, 2018). However, the government should consider the space availability of natural areas and land ownership.

Figure 6. Design concept

Most of all, the concept of this study is to conduct a range of ecological strategies, through science and art, starting from observations, GIS analysis, theoretical approaches, until landscape design. Nevertheless, ecological contagious is important and it is beneficial because it enables urban area especially riverscape provide many open spaces which have both social and natural aspects bonding together with tremendous ambiance.

4. Conclusions
In conclusion, from this study, ecological contagious (eco-contagious) can be achieved as a landscape corridor through GIS approaches using least-cost path tool and sinuosity calculation. The result shows that sustainable urban landscape as a big picture can be approached by one of strategies that is making network the ecological aspect in river area. The site location is unique because of Bogor Botanical Garden (BBG). To make a sophisticated way the source of BBG can be flourished by eco-contagious approach. There are four phases in this study including of (1) observation or site visit in the study area; (2) GIS approach (i.e. least-cost paths (LCP) analysis) of the landscape; (3) sinuosity calculation; (4) superimposed; and (5) green open spaces design. This phases are the process to achieve the eco-contagious concept. Nonetheless, the design of this concept is critical, because from the analysis the triangulation is needed to detailing the design and the real site condition. This is why, research for design by using testing the design is also determined. The result is that there are four areas that are proposed (blow-up) and designed as a patches of green open space that can be a social space and conservation area. To sum up, the design that we consider it is not only about a black-box approach but a systematic way with various strategies and analysis so that we can calculate a possibility and availability to
minimize failure. Therefore, research and design are part that cannot be divided for landscape architecture in narrowing the concept of eco-contagious in sustainable urban landscape.

5. References

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